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BULLETIN
OF THE
AMERICAN MATHEMATICAL SOCIETY

THE OCTOBER MEETING IN NEW YORK

The three hundred twenty-fifth meeting of the American Mathematical Society was held at Columbia University on Saturday, October 26, 1935. The attendance included the following one hundred nineteen members of the Society:

R. P. Agnew, C. B. Allendoerfer, R. L. Anderson, R. G. Archibald, H. E. Arnold, M. F. Becker, Felix Bernstein, Garrett Birkhoff, L. M. Blumenthal, Salomon Bochner, Joseph Bowden, H. W. Brinkmann, A. B. Brown, A. D. Campbell, E. W. Chittenden, J. A. Clark, J. A. Clarkson, W. B. Coleman, George Comenetz, E. G. H. Comfort, Richard Courant, H. B. Curry, J. H. Curtiss, R. L. Dietzold, E. J. Finan, D. A. Flanders, Edward Fleisher, M. M. Flood, Tomlinson Fort, Jeanette Fox, J. S. Frame, C. W. Franklin, Philip Franklin, T. C. Fry, B. P. Gill, L. M. Graves, S. L. Greitzer, C. C. Grove, Marshall Hall, Morris Halperin, Alan Hazeltine, Robert Henderson, E. H. C. Hildebrandt, Einar Hille, Lulu Hofmann, Harold Hotelling, E. M. Hull, R. A. Johnson, H. M. Kammerer, E. R. van Kampen, Edward Kasner, L. S. Kennison, J. R. Kline, M. S. Knebelman, B. O. Koopman, A. W. Landers, R. E. Langer, Solomon Lefschetz, Madeline Levin, E. R. Lorch, L. A. MacColl, N. H. McCoy, H. M. MacNeille, H. F. MacNeish, W. T. Martin, A. E. Meder, A. K. Mitchell, Morris Monsky, Deane Montgomery, Marston Morse, S. B. Myers, D. S. Nathan, C. A. Nelson, John von Neumann, C. O. Oakley, Alta Odoms, Oystein Ore, F. W. Owens, H. B. Owens, W. F. Penney, E. L. Post, Walter Prenowitz, R. G. Putnam, Hans Rademacher, W. C. Randels, J. F. Randolph, M. S. Rees, F. G. Reynolds, Moses Richardson, J. F. Ritt, S. L. Robinson, Benjamin Rosenbaum, I. J. Schoenberg, Jacob Sherman, Max Shiffman, J. A. Shohat, C. G. Shover, James Singer, Abraham Sinkov, L. L. Smail, P. A. Smith, W. M. Smith, V. E. Spencer, A. H. Sprague, J. M. Thomas, C. B. Tompkins, A. W. Tucker, J. L. Vanderslice, I. L. Van Dyck, Oswald Veblen, J. L. Walsh, G. C. Webber, Louis Weisner, M. E. Wells, S. S. Wilks, W. A. Wilson, Aurel Wintner, H. P. Wirth, Max Zorn.

The meeting opened on Saturday morning with two sectional sessions, one of algebra, and one of analysis and geometry. There was a general session in the afternoon at which Professor J. L. Walsh gave an address on *Interpolation by rational functions.*

There was no meeting of the Council or of the Trustees.

Titles and cross references to the abstracts of the papers read at this meeting follow below; papers whose abstract numbers are followed by the letter *t* were read by title. The papers numbered 1 to 10 were read before the section of algebra, Professors Philip Franklin and N. H. McCoy presiding; those numbered 11 to 22 before the section of analysis and geometry, Professor Einar Hille presiding; those numbered 23 to 41 at the general session, Professor J. F. Ritt presiding. Mr. Herschfeld was introduced by Professor Ritt, Mr. Perlin by Professor Graves, Dr. Robertson by Professor Kline, and Dr. Siegel by Professor Kline.

1. *A theorem on matrices*, by Dr. E. J. Finan. (Abstract No. 41-11-359.)

2. *Isometric geometry methods in determinant theory*, by Dr. L. M. Blumenthal (National Research Fellow). (Abstract No. 41-9-348.)

3. *On the characteristic roots of matric polynomials*, by Professor N. H. McCoy. (Abstract No. 41-9-351.)

4. *On the simple group of order* 5616, by Dr. Abraham Sinkov. (Abstract No. 41-11-372.)

5. *Generalizations of some theorems of Schur on irreducible polynomials*, by Mr. Benjamin Rosenbaum. (Abstract No. 41-9-347.)

6. *The equation* $2^x - 3^y = d$, by Mr. Aaron Herschfeld. (Abstract No. 41-9-338.)

7. *The composition of modular algebras*, by Mr. Garrett Birkhoff. (Abstract No. 41-11-356.)

8. *Criteria for the compositeness of finite groups*, by Professor Louis Weisner. (Abstract No. 41-11-409-*t*.)

9. *On Waring's problem and its generalization*, by Professor L. E. Dickson. (Abstract No. 41-11-406-*t*.)

10. *Polyadic groups* (preliminary report), by Dr. E. L. Post. (Abstract No. 41-11-408.)

11. *Discontinuous groups in topological spaces* (preliminary report), by Dr. Max Zorn. (Abstract No. 41-9-352.)

12. *A note on continuous deformations locally one-to-one*, by Dr. C. B. Tompkins. (Abstract No. 41-9-339.)

13. *Conformal geometry of horn angles*, by Professor Edward Kasner and Dr. George Comenetz. (Abstract No. 41-11-365.)

14. *On the singular solutions of algebraic differential equations*, by Professor J. F. Ritt. (Abstract No. 41-11-367.)

15. *Maxima and minima of finite sums*, by Professor Tomlinson Fort. (Abstract No. 41-11-360.)

16. *Note on asymptotic expressions for the zeros of Hermite and Laguerre polynomials*, by Miss V. E. Spencer. (Abstract No. 41-11-373.)

17. *A system of Riquier and the tensor calculus*, by Mr. L. B. Robinson. (Abstract No. 41-11-370-*t*.)

18. *Classification of measurable functions*, by Professor Philip Franklin. (Abstract No. 41-11-361.)

19. *A particular sequence of step functions*, by Mr. Nelson Dunford. (Abstract No. 41-11-357-*t*.)

20. *On a theorem of H. Hopf*, by Professor Hassler Whitney. (Abstract No. 41-11-376-*t*.)

21. *Linear operations on L_p to L_q*, by Mr. Nelson Dunford. (Abstract No. 41-11-358-*t*.)

22. *A function not constant on a connected set of critical points*, by Professor Hassler Whitney. (Abstract No. 41-11-407-*t*.)

23. *On mechanical quadratures*, by Professor J. A. Shohat. (Abstract No. 41-11-371.)

24. *Relative conformal invariants*, by Professor Edward Kasner. (Abstract No. 41-11-364.)

25. *Rank correlation and tests of significance involving no assumptions of normality*, by Professor Harold Hotelling and Margaret Richards Pabst. (Abstract No. 41-11-363.)

26. *A new definition of limit*, by Mr. Garrett Birkhoff. (Abstract No. 41-9-355-*t*.)

27. *A class of multi-symmetric polyhedra*, by Mr. Michael Goldberg. (Abstract No. 41-11-362-*t*.)

28. *On Monge's differential equation*, by Professor J. W. Lasley. (Abstract No. 41-9-354-*t*.)

29. *On rational automorphs of binary quadratic forms*, by Professor Gordon Pall. (Abstract No. 41-9-343-*t*.)

30. *Sufficient conditions for a minimum in the problem of Lagrange with isoperimetric conditions*, by Mr. I. E. Perlin. (Abstract No. 41-9-349-*t*.)

31. *On the univalency of the Cesàro partial sums of a univalent function*, by Dr. M. S. Robertson (National Research Fellow). (Abstract No. 41-11-369-*t*.)

32. *On the coefficients of an odd schlicht function*, by Dr. M. S. Robertson (National Research Fellow). (Abstract No. 41-11-368-*t*.)

33. *Mean values of arithmetic functions in number fields*, by Dr. C. L. Siegel. (Abstract No. 41-9-344-*t*.)

34. *On the algebraic integrals of the restricted three-body problem*, by Dr. C. L. Siegel. (Abstract No. 41-9-346-*t*.)

35. *The volume of the fundamental domain for some infinite groups*, by Dr. C. L. Siegel. (Abstract No. 41-9-345-*t*.)

36. *On confidence ranges for the median and other expectation distributions for populations of unknown distribution form*, by Dr. W. R. Thompson. (Abstract No. 41-11-374-*t*.)

37. *Concerning spaces of uncountably many dimensions*, by Dr. C. W. Vickery. (Abstract No. 41-9-350-*t*.)

38. *Elimination of the continuum-hypothesis from algebra*, by Dr. Max Zorn. (Abstract No. 41-11-377-*t*.)

39. *On Schur's generalization of Fermat's theorem*, by Dr. Max Zorn. (Abstract No. 41-9-353-*t*.)

40. *On the preservation of angles at a boundary point in conformal mapping*, by Dr. S. E. Warschawski. (Abstract No. 41-11-375-*t*.)

41. *On prime numbers of real quadratic fields in rectangles*, by Professor Hans Rademacher. (Abstract No. 41-11-366-*t*.)

J. R. KLINE,
Associate Secretary

ENCYKLOPÄDIE—III 2, 7–13

Encyklopädie der mathematischen Wissenschaften mit Anschluss ihrer Anwendungen. Band III 2, Hefte 7–13. Teubner, Berlin and Leipzig.

The early parts on algebraic geometry appeared more than twenty years ago. The manuscripts of some of the other parts were also prepared, but various circumstances prevented their publication at that time. Most of these have now been brought down to date, but in two cases the deaths of their respective authors have made this impossible.*

Mehrdimensionale Räume. By C. Segre. Band III 2 A, Heft 7. 1920. Pages 769–972.

Corrado Segre (1864–1924) had been interested chiefly in the geometry of hyperspace prior to and a few years after the beginning of the present century. Because of the variety and value of his contributions to this field, it was natural for him to be chosen to write the monograph on hyperspace for the Encyklopädie; indeed, as Loria says in his biography of Segre,† the plan of a great encyclopedia of mathematics could scarcely be thought of without designating him to discuss the geometry of n dimensions.

In the monograph, a bibliography is given first with abbreviated titles for future reference, followed by a short table of frequently used symbols. The historical introduction covers sixteen pages. It contains numerous references and copious footnotes. Here and all through the monograph, the footnotes contain discussions of the references which are very valuable.

Following the historical introduction, the monograph is divided into ten large subdivisions, which we shall call chapters. The chapters are further subdivided into sections, of which there are forty-seven, numbered continuously throughout the monograph.

In the first two chapters, the elementary properties of hyperspace and the generalized principles of projective geometry applied to n dimensions are developed.

The third chapter deals with hyperquadrics—their properties, collineations under which a manifold of the second order is invariant, and systems of hyperquadrics. This is followed by a short chapter on null systems and the linear line complex.

In Chapter 5, hyperspace curves are discussed in detail, first as to their characteristics and their generation by intersecting manifolds. The formulas of Veronese are then derived, followed by a treatment of normal curves and the postulation of curves on surfaces. The last two sections are devoted to rational and elliptic curves.

Similarly, in Chapter 6, surfaces in hyperspace are discussed. The generation of surfaces by intersecting manifolds and the tangent spaces of surfaces

* In what follows, the separate parts are reviewed by different persons, under the general direction of Virgil Snyder.—THE EDITORS.

† Annali di Matematica, (4), vol. 2 (1924–25), p. 9

are treated. Then follows a discussion of ruled surfaces, rational surfaces, Veronese's quartic and its generation in S_n, and finally surfaces whose plane sections have a given genus.

The next chapter deals with manifolds of dimension greater than two, the discussion being similar to that for surfaces. Hypersurfaces are studied in detail, including their characteristics, systems, postulation, intersections with manifolds. Seven pages are given to cubic hypersurfaces. Manifolds generated by a single infinity of lines and other special manifolds are treated in the latter part of the chapter.

In Chapter 8 there are developed geometries in which any linear S_k is the element. Chapter 9 contains a very brief discussion of the principle of correspondence in S_n.

In Chapter 10, the concept of hyperalgebraic geometry is presented. The manifolds of hyperalgebraic geometry have equations in the coordinates of conjugate imaginary elements. The study of linear transformations connecting hyperalgebraic manifolds leads to antiprojectivities and their special cases. An antiprojectivity is a linear transformation in which the anharmonic ratios of four elements and their four corresponding elements have conjugate imaginary values. These ideas were developed by Segre in 1890–91. He seems not to have known that they had been treated previously in a thesis by a Danish geometer, C. S. Juel, under the name of "symmetralities." This thesis was published in Copenhagen in 1885 and later in the Acta Mathematica (1890). No reference to Juel is given in this monograph.

There is no separate index since the volume is indexed as a whole. The brief but pithy contents, however, present an excellent outline of the subject matter.

There is evidence that Segre did not particularly enjoy writing this monograph—in the decade or more preceding, he had become interested in other phases of mathematics. He did the work, however, with an exactitude, finesse, and comprehension that have rarely been equalled. One who studies it will readily agree with Loria* that the difficult task of writing a digest of the geometry of n dimensions was performed with such great care and insight that this article deserves to serve as a model for future similar works.

T. R. HOLLCROFT

Algebraische Liniengeometrie. By Konrad Zindler. Band III 2, Heft 8. December, 1922. Pages 973–1228.

The author of this report had three decided advantages: the subject was comparatively new and sharply defined, he had contributed a considerable part of the literature himself, and was still in the prime of productivity when the report was written. The results of these conditions are everywhere apparent in a comprehensive and well-rounded product.

It is curious that a subject that was practically unknown three quarters of a century ago is now an indispensable tool in algebraic and projective geometry besides furnishing a vast laboratory in the foundations of mathematics.

The first section, about 100 pages, is devoted to the elementary concepts,

* G. Loria, loc. cit.

systems of coordinates, methods of mapping, linear transformations, and an exhaustive discussion of the linear complex, pencils of complexes and of reguli.

The remaining sections are devoted respectively to algebraic complexes, congruences, and ruled surfaces. The quadratic complex and systems of non-singular quadratic complexes are discussed in such detail as to supply a helpful addition to existing literature in the way of a hand-book. Congruences are nearly as fully treated, especially those contained in a quadratic complex. Applications to the Kummer surface are even better coordinated than in the existing textbooks.

The summary of algebraic ruled surfaces, comprising over a hundred citations, is exceptionally well done. Since it was written, the only important additions are the book of Edge and the essay of Wiman in the Acta Mathematica.

The report was published in the most trying post-war period. This explains the omission of three chapters: differential line geometry, geometry of the sphere, and the use of other space elements, each of which could contribute materially to the usefulness of the report.

VIRGIL SNYDER

Algebraische Raumkurven und abwickelbare Flächen. By K. Rohn and L. Berzolari. Band III 2 B, Heft 9. July, 1926. Pages 1229–1436.

This volume covers approximately a century of research on space curves and developable surfaces. The author is well fitted for the task, having been familiar with and a contributor to the field for more than a third of that time. There is an abundance of material and its arrangement shows very careful planning, for it reads more like a textbook than the source book it really is.

In some places the material is covered in full, in others it is barely sketched. However, in either case the reader is liberally supplied with references. The references given are frequently really footnotes as they contain additional and valuable information upon the subject.

The first two-thirds of the book deals principally with general properties of space curves and their developable surfaces. It begins with some definitions and representations of a space curve, and includes many of the fundamental properties resulting from these definitions. Singular points are introduced early, followed by the Cayley and other formulas. The geometry on a curve and the classification of curves are discussed at some length.

The latter third of the book deals primarily with particular curves and surfaces. Rational curves of order four, five, six, and seven, and irrational curves of order four, five, and six are discussed. Some other special curves as well as special systems of curves are also discussed.

AMOS BLACK

Spezielle Algebraische Flächen. By W. Fr. Meyer. a. *Flächen dritter Ordnung.* Band III 2, Heft 10. 1928. Pages 1437–1531; b. *Flächen vierter und höherer Ordnung,* Heft 11. 1931. Pages 1533–1779.

The discussion of cubic surfaces is divided into two parts. The first includes the older historic treatment, mapping, and the development of properties; the second part reviews the prize papers of Cremona and Sturm, and outlines

the Segre projection, Juel's topologic cubic surface, the theory of binary invariants applied to space cubic curves, and the theory of groups.

The surfaces of the fourth and higher orders can not be so easily classified, and the author considers his material in thirteen sections, confining his attention almost entirely to special types of quartic surfaces. The reader is given an introductory survey of curves and invariants on the quartic surface and of Kummer's essay on the F_4 with a nodal conic, followed by a discussion of the F_4 with a double conic developed according to Clebsch's method of mapping the surface on a plane and including the cyclides; of the F_4 with a double line, the F_3, F_2, $\cdots$, with singular curves, and rational surfaces; and of the F_4 with a triple point, the Steiner surface, and the F_4 with a three-fold line. The F_4 with less than sixteen double points comes next, followed by the Weddle and Kummer surfaces, with the surface of Cayley's tetrahedroid, and its metrical interpretation as Fresnel's wave surface. The line geometry of the Kummer surface as well as its representation by hyperelliptic functions of two variables is included. The treatise closes with a consideration of ruled surfaces and of the metric F_4, emphasizing those derived from quadrics.

In the first volume the theory of the twenty-seven lines on the cubic surface is treated at some length, due emphasis being given to the surfaces with multiple points. Various methods of classification and of generation are based upon this theory. The several processes of mapping are presented in such detail that the reader can get a complete and accurate grasp of the subject. A particularly valuable feature is the careful analysis of existence proofs, postulation, and porisms. A few omissions of recent papers have been noted but on the whole the literature has been well covered and the topics skillfully arranged.

There is more overlapping of material in the various sections of the second volume, due perhaps to the fact that surfaces of above the third order do not lend themselves to classification under a small group of distinct headings. Practically all known theorems of a general nature are negative, for example, the statement that a general surface of order greater than three contains no curves simpler than the plane sections.

The topics treated are generally explained fully in the text, affording a comprehensive survey. In the compilation of such an encyclopaedic character as here attempted it is obviously impossible to give complete references, but it is regrettable that so many papers have not received recognition. Several additions have been given in the appendix, but the list remains very incomplete. Godeaux and Sharpe have each been referred to only once, and Snyder's numerous articles including his classification of Dupin cyclides and his list of ruled surfaces of order six (which is complete according to Wiman) have been omitted.

Not infrequent typographical errors have been noted, the majority referring to dates of the papers cited. An example of confusion thus caused is seen on page 1543 in note (4), where the Valentiner reference should be page 22 instead of page 223; the de Jonquières reference (Comptes Rendus, vol. 106 (1888), pp. 209, 526, 907) should not be divided into two separate references (vol. 106 (1887), pp. 526, 907, and vol. 107 (1888), p. 209); and the reference to P. W. White (Cambridge Philosophical Society Proceedings, vol. 21 (1920), p. 116) should be to F. P. White (vol. 21 (1922), p. 216). This last reference has

also been given incorrectly in a different form on page 1518. On both pages 1501 and 1611 the paper attributed to G. Veronese (Mathematische Annalen, vol. 24 (1884), p. 313) is an article by C. Segre; the Veronese reference should be Mathematische Annalen, vol. 19 (1881), p. 161. Other types of misprints occur, as on page 1465, line 19 up, C_4 should be C_3; Sekanten should be Bisekanten; on page 1495, line 19 up, Doppel should be Torsal.

With the completion of these two volumes the study of algebraic surfaces will be greatly facilitated. Notwithstanding the omissions, they make a notable addition to the essential literature of the subject. A laborious work has been ably completed.

EVELYN CARROLL-RUSK

Algebraische Transformationen und Korrespondenzen. By L. Berzolari. Band III 2 B, Heft 12. 1933. Pages 1781–2219.

This is the twelfth and last number of the volume on algebraic geometry, and it brings the standard of excellence of the Encyklopädie to a new high level. Berzolari has done an admirable piece of work in this well written, carefully organized discussion of algebraic correspondences and transformations. He has woven the researches of some 960 authors into a harmoniously unified treatment of the subject which will be of immense assistance to algebraic geometers. This book overlaps to some extent Bulletins 63 and 96 of the National Research Council, but to a greater degree it correlates and supplements these bulletins.

The reviewer finds no essential omissions and no errors of fact or typography. The book is divided into eight quite unequal divisions which might be called chapters, and a brief summary of the topics considered will give some idea of the thoroughness of the author's study.

I. *Einleitende Definitionen und Eigenschaften.* This chapter is concerned with such topics as the definitions of algebraic correspondences between algebraic manifolds, reducible and irreducible correspondences, and branch points. Invariant relationships, such as the formulas of Zeuthen and Noether, are discussed.

II. *Algebraische Korrespondenzen und Korrespondenzprinzipien in linearen und nichtlinearen Gebieten.* Algebraic correspondences between two rational curves, (2, 2) correspondences, multi-linear correspondences, and various theorems on correspondences are developed in this chapter.

III. *Algebraische Korrespondenzen und Korrespondenzprinzipien für algebraische Kurven beliebigen Geschlechts.* This is the longest chapter in the book and covers some 125 pages. Among the many topics which are taken up are the Cayley-Brill theorem, systems of several correspondences between the points of a curve, the correspondence theory of A. Hurwitz, Severi's geometrical treatment of the general correspondence theory, and the valence of a correspondence according to Burkhardt and Zeuthen. There is also a discussion of algebraic correspondences between algebraic curves from the point of view of analysis situs, and items such as Zeuthen's rule for the multiplicity of a coincidence point in an algebraic correspondence, grade and genus of a correspondence, symmetric and semisymmetric correspondences. The transcendental theory is brought in by a discussion of the work of C. Rosati and of G. Scorza on Abelian

integrals and the theory of the Riemann matrix, reducible Abelian integrals of the first kind, singular correspondences, Hermitian correspondences, involutions on algebraic curves, Schubert's formula and arithmetic criteria of Castelnuovo and of Severi, the Jacobian manifold V_p of a curve of genus p, and automorphic birational transformations of an irreducible curve are considered in the latter part of the chapter.

IV. *Birationale (oder Cremona-) Transformationen zwischen zwei linearen Räumen von zwei oder mehreren Dimensionen.* The study of transformations is started with a discussion of the plane Cremona transformation and the nature and properties of the fundamental elements. The Cremona group, periodic and involutorial transformations, the types of plane involutions, and the quadratic transformation are taken up in turn. The transformations of ordinary three-space are then considered with emphasis on the quadratic, the bilinear cubic, and the monoidal transformations. The chapter closes with sections devoted to transformations of higher space and to regular groups of Cremona transformations.

V. *Mehrdeutige Korrespondenzen zwischen zwei linearen Räumen von zwei oder mehreren Dimensionen.* This chapter goes into the theory of rational transformations between two planes and between three-spaces. Algebraic correspondences with arbitrary indices between two planes and between two three-spaces are also considered together with higher null transformations and general involutions in spaces of two or more dimensions.

VI. *Anwendungen.* In this short chapter on applications the author writes on mapping, reduction of singularities of curves and surfaces, and the reduction of linear systems of algebraic curves and surfaces to types by means of Cremona transformations.

VII. *Ebene Abbildung von rationalen Flächen.* This short chapter is devoted to the questions of rationality of a surface, real rational surfaces, the work of Comessatti, and mapping on multiple planes.

VIII. *Andere besondere Abbildungen und algebraische Korrespondenzen.* In the last chapter of the book rational manifolds of three dimensions and connexes are considered.

L. A. DYE

General Index. Band III 2, Heft 13. September, 1934. Pages 2221–2331.

The use of an index is not uniform throughout the work. Thus Analysis, Teil I, has neither subject index nor list of names mentioned. All the other parts have a subject index and *Analysis*, Teil 3, has a list of names. At the end of the second volume on geometry appears a 45-page index of subject matter, pertaining to Teil 2 only, and this is followed by a 70-page list of names cited in all of the 5000 pages on geometry. It was a monumental task and may have some use, but if so, in ways other than serving as a finder when applied to a name often cited. The name most frequently appearing in this list is Felix Klein, with over 500 citations; Arthur Cayley is a close second.

VIRGIL SNYDER

ZYGMUND ON TRIGONOMETRIC SERIES

Trigonometric Series. By Antoni Zygmund. Warszaw, Monografje Matematyczne, Volume V, 1935. iv+320 pp.

It has been a repeated privilege of the reviewer to express his appreciation of the high standards and excellent quality of the series of monographs of which Volume V is now under his consideration. Each volume of the series published so far represents an important event in the development of mathematical research, and the present volume in this respect is second to none of its predecessors. If one looks through the long list of books on Fourier series one can not help feeling that even the bulkiest of them are far from giving an adequate picture of the present status of the field. The non-existence of a monograph giving such a picture was very badly felt not only by the beginners but also by specialists, and the failure of so many attempts to write a real book on Fourier series created an impression that the task was almost hopeless. The author of the present monograph completely succeeded in dispelling this "inferiority complex" and produced a book which not only introduces the reader into the immense field of the theory of Fourier series but at the same time almost imperceptibly brings him to the very latest achievements, many of them being due to the author himself. The style of the book is rigorous and vigorous and the exposition elegant and clear to the smallest details.

Without wasting his and the reader's time on unessential things the author endeavors to treat each special problem by methods throwing light on the problem from a general standpoint, and showing the place occupied by it in the whole structure. Such a method of exposition will prove to be extremely helpful to a neophyte and will delight a specialist.

Although Zygmund's monograph is far from being the bulkiest of all books written on Fourier series, it certainly contains the richest material. In fact there are but very few topics of importance omitted in it. Thus it is futile to attempt to present here an adequate idea of the subjects treated in the book, and we shall have to restrict ourselves to a very brief description by chapters. Chapters 1 (Trigonometrical series and Fourier series) and 2 (Fourier coefficients, tests for the convergence of Fourier series) are of an introductory character. However, even at this stage the author gives a rather complete discussion of various convergence tests and their mutual relationships, of the order of Fourier-Lebesgue and Fourier-Riemann coefficients, and of operations on Fourier series. Chapter 3 (Summability of Fourier series) contains a rapid but inclusive and elegant discussion of Cesáro and Abel summability of Fourier and Fourier-Stieltjes (derived) series and their conjugates. Chapter 4 (Classes of functions and Fourier series) deals with necessary and sufficient conditions which have to be satisfied by the Fourier series of a function in order that this function should belong to a certain specified function space (such as L_p, and a more general space L_ϕ, continuous, bounded and measurable, and the like). The generalized Parseval identity and the theory of factor sequences transforming one class of functions into another find their appropriate place here. A

systematic use of notation and results of the theory of linear operation in abstract spaces and of general inequalities based on the theory of convex functions appear here as natural and powerful tools. Chapter 5 (Properties of some special series) treats of topics like convergence factors, lacunary series, and certain power series as a source of "Gegenbeispiele" of various kinds. Considerable use is made of the theory of Rademacher series. The subject of Chapter 6 (The absolute convergence of Fourier series) is clear from its title. Aside from the classical results of Fatou, Lusin, and Denjoy, it contains a discussion of exponents of convergence of Fourier coefficients of functions satisfying Lipschitz conditions, of the absolute convergence of some lacunary series, and closes with a recent important theorem of Wiener and its extensions. Chapter 7 (Conjugate series and complex methods in the theory of Fourier series) contains a wealth of material concerning the conjugate of a Fourier series. Extremely simple proofs of fundamental inequalities of M. Riesz and of a theorem of Hardy and Littlewood, and Fejér deserve a particular mention. Chapter 8 (Divergence of Fourier series, Gibbs' phenomenon) contains, among many other important topics, a treatment of Gibbs' phenomenon for Cesáro sums of a Fourier series (Cramér's theorem) and an exposition of the famous example of an everywhere divergent Fourier series of Kolmogoroff. Chapter 9 (Further theorems on Fourier coefficients, integration of fractional order) is devoted to an exhaustive exposition of the theory of Fourier coefficients, which originated in the classical theorem of Young-Hausdorff-F. Riesz, and was developed by Hardy and Littlewood, Paley, and the author himself. The comparatively recent but already classical theorem of M. Riesz concerning the convexity of moduli of linear transformations in abstract spaces is of course the main tool here. For lack of space we omit the description of the very interesting Chapter 10 (Further theorems on the summability and convergence of Fourier series) and pass on to the next, Chapter 11 (Riemann's theory of trigonometrical series). This chapter is a masterpiece of concise and clear exposition. It contains, together with the classical results, an exposition of the theory of formal multiplication of trigonometric series developed by Rajchman and Zygmund, of uniqueness and multiplicity sets, and, as a final climax, the latest investigations of Verblunsky concerning the uniqueness problem for Abel summable series. The last Chapter 12 (Fourier's integral) gives a very elegant exposition of the Plancherel-Titchmarsh theory of Fourier transforms and of fundamental results of the theory of representation of a function by means of Fourier integrals. This chapter should be considered as an introduction to the theory of Fourier integrals—a vast field whose "adequate treatment would require a separate book," as the author rightly states in his preface.

Each chapter is supplied with numerous "Miscellaneous theorems and examples." They cover considerable ground by themselves, and unlike the usual type of "exercises" of this kind, are supplied with hints and references sufficient to make them more than a collection of puzzles. The book closes with a substantial bibliography. The typography and general setting of the book are excellent, although the number of misprints (including one or two lapses) is more than negligible. On the whole the author should be congratulated upon producing not only a good book but *the* book on Fourier series, the study of which will benefit the beginners and specialists alike through years

to come, by bringing within their immediate reach the best of what has been achieved in the theory of Fourier series.

J. D. TAMARKIN

ZARISKI ON ALGEBRAIC SURFACES

Algebraic Surfaces. By Oscar Zariski. Ergebnisse der Mathematischen Wissenschaften, Volume 3, Berlin, 1935. v+198 pp.

We are facing today, in the birational geometry of surfaces and varieties, more than in any other chapter of mathematics, the sharp need of a thoroughgoing and critical exposition. In a subject reaching out in so many directions, the task is bound to be arduous. Nevertheless it is surely urgent and for two reasons. In the first place, a systematic examination of the positions acquired is destined to be of considerable value in subsequent campaigns. In the second place, the territory already conquered and safely held is exceedingly beautiful and deserves to be admired by tourists and not merely by members of the vigorous, but small, conquering army. To speak less metaphorically, in this quarter of mathematics "cantorian" criticism has not penetrated as deeply as in others. This has resulted in a widespread attitude of doubt towards the science, which it would be in the interest of all to dispel as rapidly as possible. Nothing will contribute more to this worthy end than Zariski's splendid book. It is indeed the first time that a competent specialist, informed on all phases of the subject, has examined it carefully and critically. The result is a most interesting and valuable monograph for the general mathematician, which is, in addition, an indispensable and standard *vade mecum* for all students of these questions.

As is well known, when one endeavors to pass from one-dimensional birational geometry to the higher dimensions, the difficulties multiply enormously. Many results do not extend at all, or if they do, they are apt to assume a far more complicated aspect or else to demand most difficult proofs.

Consider for example these two questions: (a) the reduction of singularities; (b) the extension of the properties of the genus of an algebraic curve. For some time we have had quite complete and satisfactory proofs of the fact that any irreducible algebraic curve is birationally transformable into a non-singular curve in some space, or to a plane curve with simple and harmless singularities. A similar result is certain to hold for surfaces and varieties. Not to speak of varieties where complete obscurity still reigns, the proof for surfaces has given rise to much confusion. In Zariski's monograph we find the first critical and complete survey of the situation ever made. From this survey it appears, incidentally, that the only "certifiable" proof now in existence is R. J. Walker's (Annals of Mathematics, April, 1935).

A similar service has been performed by Zariski as regards the theory of the *irregularity* q, the analog of the genus p for a surface. The genus p of an algebraic curve is susceptible of four unrelated definitions: projective, birational-geometric, transcendental, topological. On passing to surfaces, these definitions give rise to different genera, which are distinct but not wholly independent.

These invariants were extensively investigated by Castelnuovo, Enriques, Picard, Severi, and in certain relatively simple cases, they enable one to separate certain important classes of surfaces (such as rational or hyperelliptic surfaces, and reguli). The central, and also most easily described result is the following: *Let q be the irregularity of an algebraic surface F ($2q$ = first Betti number of F) and let $|C|$ denote a complete linear system of algebraic curves in F. Then $|C|$ is a member of an algebraic family whose dimension never exceeds and generally equals q.* The possible dimensions may be given when the structure of the period-matrix of the Picard integrals (linear integrals) of the first kind is known. This fundamental theorem was obtained by the combined efforts of the above geometers together with Humbert and Poincaré. Zariski's careful analysis has shown that the one solid proof is Poincaré's, which is last in date, and wholly analytical. Indeed the perusal of Zariski's book shows clearly that in this domain the most solid ground is always to be found wherever analysis and topology predominate, for example in the theory of the base (investigations of Picard, Severi, and Lefschetz). It serves also to confirm the reviewer's opinion of many years standing, that it would be most desirable to develop the whole theory from the function-theoretic point of view, as a chapter in the general theory of analytic functions of several variables. For that matter, this should likewise be done from the point of view of modern algebra, although in this direction there is some danger of losing much of the geometric charm.

The preceding remarks risk leaving the reader with the unjust impression that Zariski has occupied himself chiefly with a critique of things long since done. As a matter of fact, this critique takes up only half of his monograph, the rest being given over to modern questions. Thus the topological structure of a surface is treated with abundant care; the recent and very striking results of Hodge are duly described; likewise there is a summary of the theory of punctual series of equivalence on surfaces recently developed largely by Severi, together with its contacts with the reviewer's topological fixed point theory. Altogether we cannot recommend this monograph too strongly to all lovers of geometry in every form. They will leave it convinced of the beauty and vitality of this most attractive branch of modern mathematical research.

SOLOMON LEFSCHETZ

SHORTER NOTICES

Moderna Teoria delle Funzioni di Variabile Reale. Parte Prima. By G. Vitali and G. Sansone. Monografie di Matematica Applicata per cura del Consiglio Nationale delle Ricerche. Bologna, Zanichelli, 1935. viii+183 pp.

This excellent booklet is the first volume of a new series of monographs on applied mathematics published under the auspices of the Italian National Research Council. It is based upon a posthumous manuscript of Vitali, edited and completed by Sansone. It gives a remarkably clear and condensed introduction to the theory of functions of a real variable. In five chapters of about 33 pages each are presented the basic facts from the theories of sets and cardinal numbers, measure, analysis of functions [measurable functions, classes of Baire, bounded variation, absolute continuity], integration, and differentiation. As is to be expected in view of the prominent role played by Vitali in the development of modern analysis, the presentation is original in many places. The typographical makeup is pleasing and of high order. A minor point of notation could perhaps be mentioned. In a modern treatment one does expect that the variable of integration and the upper limit should not be denoted by the same letter; the authors fail to observe this desideratum.

Those preparing to give a course on real variables will find this book highly stimulating and useful. In the hope that the further publications in this series will come up to the high standard set by the first one the mathematical world will eagerly await successors to this monograph. A treatise by Sansone on expansions in orthogonal series seems to be the next in order.

EINAR HILLE

The Dilemma of Modern Physics. By D. E. Richmond. New York, G. P. Putnam's Sons, 1935. xiii+120 pp.

This small book attempts to give in a non-technical form some idea of the revolution which has taken place during the past quarter century in the domain of physics. The following chapter headings give a good idea of the matters treated: *The classical physics*; *The quantum theory*; *New developments*; *The dilemma* (that is, waves versus particles); *The principle of uncertainty*; *On meaning*; *Causality and probability*. In his preface the author explains that the book arose from a series of semi-popular lectures on the modern quantum theory. It is the present reviewer's opinion that the book itself is a good instance of what a semi-popular book should be.

F. D. MURNAGHAN

Aristotle's Theory of the Infinite. By Abraham Edel. Privately printed, New York, 1934. For sale at The Journal of Philosophy, Inc., 515 W. 116th Street, New York City. Price $1.00. 102 pages.

Here we have a careful inquiry into Aristotle's theory of the infinite in which the principal emphasis lies in the attempt to understand how Aristotle

himself conceived the problem and what he says in his discussion of it. The author has brought a discriminating intelligence to bear upon his task and has presented an analysis which is worthy of the careful attention of students of Aristotle. The principal interest of the essay is for those whose attention is centered mainly upon the philosophical aspects of the infinite; consequently this is not the place for a detailed review of it. But a fact frequently overlooked should be pointed out here, namely, that in his discussion of the infinite by way of addition, Aristotle makes manifest a clear understanding on his part of the essential elements involved in the notion of convergence of an infinite geometric series whose ratio is less than unity. See *The Physics*, Book 3, Chapter 6 (206b 3–33).

R. D. CARMICHAEL

Théorie des Probabilités. By P. Van Deuren. Paris, Gauthier-Villars, 1934. xvii+546 pp.

This treatise on probability, written by Professor Van Deuren after teaching the subject for thirty years at l'École Militaire de Belgique, is very well organized. It constitutes "Tome Premier," introductory to a volume dealing with applications. The style is formal; indeed, the author intended to make it "didactique." The material throughout the book is in general very well arranged and well chosen for the purpose in view.

To avoid the much criticized use of "equally likely" events to define probability, the author adopts a quasi-axiomatic method. He states (p. 4): "La probabilité est un notion première intuitive. Elle apparaît comme une grandeur qui mesure a l'aide des données (4), la vraisemblance actuelle, ou apparence de vérité de l'arrivée d'un événement." This second statement virtually leaves the "intuitive" notion undefined, except that probability is required to be a magnitude, "grandeur." Later the author associates such a magnitude with a real number. Certain properties of probability are then set forth as principles or theorems—many of which might well be regarded as axioms—collectively building up the notion of probability. These properties include the additive law for incompatible events, and laws for composite events—such as the law that the probability of a composite event cannot exceed that of any constituent. When a set of incompatible events exhausts all the possibilities, and the probabilities therefor are all equal, these events are called "chances," and are said to arrive "ou hasard."

The book deals primarily with the classical theory of probability. There are very few references to other writers. Modern topics, such as small samples, are not included. Nevertheless, the size of a sample is a matter of great concern. The author determines the minimum size of a sample—the least number of trials or observations—to make valid various approximations. An event, with a probability of at least 0.99, he defines as "pratiquement certain"—following artillery usage. Using this measure of practical certainty, he determines practical domains of certainty, practical moments, practical coefficients of concentration, and so on. It is difficult in a few words to give an adequate idea of the thoroughness with which these approximations are introduced and controlled; this is one of the outstanding and unique features of the book.

A liberal use is made of definitions. A variable "concentrates" when its standard deviation approaches zero, by reason of a change in a parameter, for instance, when the number of trials increases indefinitely; it "concentrates normally" when the standard deviation divided by the range approaches zero, as is the case with the ratio of occurrences to trials in Bernoulli's theorem. Unfortunately, however, the "coefficient" of concentration (p. 285) and the "index" of dependence (p. 177) exhibit inverse variation. Zero concentration, as registered by the coefficient, occurs when the concentration is the most complete or highest; and zero dependence implies (p. 181) a linear relation—that is, strict functionality. The general index of dependence (p. 185) is actually the Pearsonian determinant R, built with coefficients of correlation; but a different notation is used. "Le domaine pratiquement certain" is an interval centered at the mean such that the probability of falling outside this interval is not greater than 0.01. The author shows (p. 298) that if the deviation of a variable from its mean does not exceed 14 times the standard deviation, it will lie in this domain. With a slight modification of the proof there given, the upper bound can be cut down to 10 times the standard deviation—the Tchebychef inequality.

The book makes extensive use of transformations, with their Jacobians. Results are generalized to n variables. Preceding the method of least squares is the more general method of the least covariant—the exponent for generalized normal frequency. The notation and symbols are thoroughgoing; but in places seem a little cumbrous. There are numerous good figures and numerous good simple illustrations; but no problems are inserted for the reader. A seven-place table for the probability integral is given, with integrand $\exp(-t^2)$, and t at intervals of 0.01. Two appendices discuss some of the controversial topics of probability. There is no alphabetical index of topics, but the table of contents is decidedly informing. The book is sell arranged, and is pleasing to the eye. Presumably it was designed primarily for military or technical students, and it is an excellent exposition of the fundamentals needed by such students. But it should be of considerable interest to the general reader also, for it contains a great deal of material not commonly dealt with in books on probability.

E. L. Dodd

NOTES

The Bubnoff's State University of Leningrad has begun the publication of a new journal: Annals, Series of Physical Science, edited by C. E. Frech.

The Seminario Matemático de la Universidad de Varsovia has begun the publication of a new journal, Acta Arithmetica, devoted to the theory of numbers and questions relating to this field. The first number was published in February, 1935.

Volume 20 of the Colloquium Publications of the American Mathematical Society, which has recently appeared, is the book by Professor J. L. Walsh, entitled *Interpolation and Approximation by Rational Functions in the Complex Domain.*

The eleventh annual Norman Lockyer Lecture established by the British Science Guild as a means of periodically directing the attention of the public to the influence of science upon human progress, was given by Sir Josiah Stamp, president of the British Association for the Advancement of Science, on November 13. The subject of the lecture was *The calculus of plenty.*

The first annual meeting of the Indian Academy of Sciences began on December 18, 1935, and was held at Bombay.

The ninth conference of the Indian Mathematical Society was held on December 19–21, 1935, at Delhi University.

The National Academy of Sciences held its autumn meeting on November 18–20, 1935, at the University of Virginia under the presidency of Dr. F. R. Lillie. At this meeting Professor Edward Kasner, of Columbia University, and Professor G. T. Whyburn, of the University of Virginia, presented papers entitled *Conformal geometry* and *Continuous transformations of certain manifolds*, respectively.

Professor Hermann Weyl, of the Institute for Advanced Study, has been elected a member of the Koninklijke Akademie van Wetenschappen te Amsterdam.

Shortly before his death Simon Newcomb (1835–1909) was by international vote listed as the leading astronomer of the world. On August 30, 1935, the Canadian Government unveiled at his birthplace in Wallace, Nova Scotia, a very fine stone monument with a bronze tablet containing a suitable inscription. One of the two principal addresses was given by Professor R. C. Archibald, of Brown University, who had published a good deal of material about Newcomb's life and work. Two of Newcomb's daughters and four of his grandchildren were present at the exercises. In November, 1935, Newcomb was elected to the Hall of Fame of New York University. He was the second president of the American Mathematical Society (1896–97), professor of mathematics and astronomy at The Johns Hopkins University (1884–94,

1898–1900), and editor-in-chief of the American Journal of Mathematics (1884–94, 1899–1900).

Professor Paul Bernays, of Zürich, is lecturing at the Institute for Advanced Study during the first semester of this academic year.

R. L. Goodstein, of Magdalene College, Cambridge, has been appointed to the post of lecturer in mathematics at the University of Reading.

Dr. Bernard Haurwitz, mathematical meteorologist, formerly of the University of Leipzig, has become a member of the department of physics at the University of Toronto.

Dr. Borge Jessen has been promoted to a professorship at Danmarks Tekniske Højskole (Royal Technical College) at Copenhagen.

Professor Theodor Kaluza, of the University of Kiel, has been appointed to a professorship in mathematics at the University of Göttingen.

Mr. Daniel Pedoe, Cambridge University Fellow, is in residence at the Institute for Advanced Study and Princeton University this academic year.

The retirement is announced of Professor Georg Rost, of the University of Würzburg.

Professor Wilhelm Wirtinger, of the University of Vienna, has retired.

Dr. E. M. Wright has been appointed the successor of the late Professor H. M. Macdonald at the University of Aberdeen.

Dr. S. F. Barber has been appointed an associate in mathematics at the University of Iowa.

Dr. L. M. Blumenthal, formerly a National Research Fellow, has been appointed an assistant at the Institute for Advanced Study.

Professor J. W. Drew, of Storer College, Harper's Ferry, W. Va., has been appointed Dean of Men, and associate professor of mathematics at Virginia Union University.

Mr. E. G. Harrell has been appointed head of the department of mathematics at Ouachita College (Arkadelphia, Arkansas).

Assistant Professor J. M. Harrington, of the Michigan College of Mining and Technology, has been promoted to an associate professorship in mathematics.

Dr. Nathan Jacobson, of Princeton University, has been appointed a lecturer at Bryn Mawr College.

Professor A. J. Maria is visiting assistant professor at Duke University this academic year.

Dr. J. R. Mayor has been appointed professor of mathematics and head

of the department of mathematics at the Southern Illinois State Teachers College.

Assistant Professor Fay Parlo, of the Michigan College of Mining and Technology, has been promoted to an associate professorship in mathematics.

Dr. F. W. Perkins, of Dartmouth College, has been promoted to an assistant professorship.

Professor Boris Podolsky, formerly at the Institute for Advanced Study, has been appointed assistant professor of mathematical physics at the University of Cincinnati.

Assistant Professor H. P. Robertson has been promoted to an associate professorship in mathematics at Princeton University. Professor Robertson is on leave of absence during this academic year and is at the California Institute of Technology and the University of California.

Assistant Professor Morgan Ward, of the California Institute of Technology, has recently been promoted to an associate professorship.

Professor C. E. Weatherburn, professor of mathematics and chairman of the professorial board of the University of Western Australia at Crawley, Australia, is the guest of the Carnegie Corporation. He is visiting mathematical institutions in this country.

The following National Research Fellows are working at the Institute for Advanced Study and Princeton University: Drs. J. A. Clarkson, Norman Levinson, W. T. Martin, F. J. Murray, and S. B. Myers.

Among the members of the American Mathematical Society who have recently entered the field of secondary teaching are the following: Dr. E. P. Northrop, at the Hotchkiss School, Lakeville, Conn.; Dr. R. S. Pieters, at the George School, Bucks County, Pa.

The following are in residence at the Institute for Advanced Study for the academic year 1935–36: Professor Gregory Breit, of the University of Wisconsin; Professor Leonard Carlitz, of Duke University; Professor E. W. Chittenden, of the University of Iowa; Dr. E. H. Cutler, of Lehigh University; Professor Arnold Dresden, of Swarthmore College; Professor Philip Franklin, of the Massachusetts Institute of Technology; Professor B. P. Gill, of the College of the City of New York; Professor L. M. Graves, of the University of Chicago; Professor S. H. Kimball, of the University of Rochester. The following from foreign universities are also in residence at the Institute: Professor Eduard Čech, of the Masaryk University, Brno; Dr. Kurt Goedel, of the University of Vienna.

The following appointments to instructorships are announced: Bethany College, West Va.: Dr. W. H. Erskine; University of Buffalo: Miss H. F. Montague; University of Chicago: Dr. Ralph Hull; Colgate University: Mr. J. F. Wardwell; Kansas State College, Mr. Paul Cramer; Lafayette College:

Dr. R. P. Bailey; Lehigh University: Dr. J. L. Vanderslice; University of Minnesota: Dr. O. K. Sagen, Dr. K. W. Wegner.

Professor E. T. Hayashi, of the Tôhoku Imperial University, died on October 4, 1935, at the age of sixty-three years.

Professor J. I. Hutchinson, of Cornell University, died from carbon monoxide poisoning on December 1, 1935.

Dr. E. W. Rice, formerly a sustaining member of this Society, died on November 25, 1935, at the age of seventy-three years.

The death of Professor Friedrich Schottky, of the University of Berlin, is announced.

Professor W. P. Webber, of Louisiana State University, died on June 26, 1935.

ABSTRACTS OF PAPERS

SUBMITTED FOR PRESENTATION TO THE SOCIETY

The following papers have been submitted to the Secretary and the Associate Secretaries of the Society for presentation at meetings of the Society. They are numbered serially throughout this volume. Cross-references to them in the reports of the meetings will give the number of this volume, the number of this issue, and the serial number of the abstract.

1. Dr. Ralph Hull: *The maximal orders of generalized quaternion division algebras.*

A generalized quaternion division algebra Q is of the form $Q=(a, Z)=Z+uZ$, where Z is a quadratic field, $u^2=a$ is rational and not the norm of an element of Z, and $Zu=uZ'$ elementwise. In this paper for each Q all maximal orders $\mathfrak{M}$, that is, maximal sets of integral elements, are determined explicitly. For any maximal order $\mathfrak{M}$ of Q, let $\mathfrak{m}_c$ be the intersection of $\mathfrak{M}$ and Z. Then $\mathfrak{m}_c$ is an order in Z with a positive rational integral conductor c, and there exists an $\mathfrak{m}_c$-ideal $\mathfrak{n}$ of Z, not necessarily either integral or regular, and a quantity λ of Z, such that $\mathfrak{M}=\mathfrak{m}_c+(\lambda+u)\mathfrak{n}$. Conversely, in terms of a special generation for each Q found by Albert (this Bulletin, vol. 40 (1934), pp. 164–177) all $\mathfrak{m}_c$, and for a fixed c, all $\mathfrak{n}$ and λ, such that $\mathfrak{m}_c+(\lambda+u)\mathfrak{n}$ is an $\mathfrak{M}$, are determined For a fixed c there are infinitely many $\mathfrak{n}$, and for each of these a rational basis is easily found. For fixed c and $\mathfrak{n}$, the finite number of λ which yield distinct $\mathfrak{M}$ are determined. A single rational basis for each $\mathfrak{M}$ is determined. (Received November 1, 1935.)

2. Professor H. J. Ettlinger and Mr. O. H. Hamilton: *Sets of functions and their limit functions.*

For sets of functions (real) on I: $0\leqq x\leqq 1$, the following theorems are proved: 1. Extension of Arzela's theorem on the necessary and sufficient condition that a set of functions converge to a continuous limit function to include absolutely continuous functions which converge to absolutely continuous limit functions. 2. Extension of Ascoli's theorem to the effect that a bounded equicontinuous set of functions has a subsequence which converges to a continuous limit function, and the corollary of Graves that if the set above is equi-absolutely continuous, the limit function will be absolutely continuous, to include the result that the original set plus all of its limit functions will be equi-absolutely continuous. 3. Any uncountable (or absolutely continuous) set of functions on I contains a bounded subsequence which has a continuous (or absolutely continuous) limit function. 4. If $f^{\alpha}(x)$ is a collection of continuous functions on I and no two of these functions cross, there is a subsequence $f_n(x)$ such that each point which lies on two or more functions $f^{\alpha}(x)$ lies on $f_n(x)$ for

some natural number n. 5. For every bounded equi-continuous collection such that the sum of a finite number of pieces itself belongs to the collection, the upper (and lower) bound functions of the set are continuous functions and are approached uniformly as limits by subsequences of the given set. (Received November 4, 1935.)

3. Mr. P. M. Pepper: *Application of geometry of numbers to a generalization of continued fractions.*

In Minkowski's Collected Works, vol. 1, p. 279, appears a paper entitled *Zur Theorie der Kettenbrüche*. There a generalization of a continued fraction, taking the form of a set of square matrices of integers, is exhibited along with an algorithm for computing these matrices. Several theorems upon which this generalization depends are stated without proof. Let ξ, η, ζ be linear homogeneous forms in the three independent real variables x, y, z having real coefficients and such that no one of these forms vanishes for any triple of integers not all zero. There exists an infinity of triples of integers x, y, z for which $|\xi\eta\zeta| < |\Delta|$ where Δ is the determinant of the three forms. Such triples can be secured for which any desired one of these linear forms is arbitrarily small in absolute value. To ξ, η, ζ are made to correspond square matrices, each consisting of three such triples, these matrices making a chain such that to each matrix there correspond three "neighboring" matrices. This chain is analogous to the sequence of convergents of a continued fraction. In this paper proofs of the above theorems are given with a derivation of the algorithm mentioned. An example will also be given. (Received November 4, 1935.)

4. Professor H. B. Curry: *A note on the associative law in logical algebras.*

A proof of the redundance of the associative law in the Principia Mathematica was published by Bernays in 1925. The present note gives an alternative proof, which is applicable to a whole class of quasi-logical systems. This proof is a refinement of one due to C. S. Peirce. (Received November 4, 1935.)

5. Professor Hassler Whitney: *Differentiable functions defined in arbitrary subsets of euclidean space.*

Let A and B be arbitrary subsets of n-space E_n. Let $f_k(x)$, $(\sigma_k = k_1 + \cdots + k_n \leqq m)$, be defined in A. If the remainders $R_k(x'; x)$ in the Taylor formulas are defined as in the Transactions of this Society, vol. 36 (1934), pp. 63–89, (3.1); and (3.2) holds at x^0 in B for each $\epsilon > 0$; we say $f(x)$ is of class C^m in A about x^0 in terms of the $f_k(x)$: $f(x)$ is $(C^m, A, x^0, f_k(x))$. If this is so at each x^0 in B, $f(x)$ is (C^m, A, B). It is shown that if $f(x)$ is (C^m, A, B), then it may be extended throughout E_n so that it is (C^m, E_n, B), generalizing Lemma 2 of the above paper; then in any open subset of B, $f(x)$ has continuous mth derivatives. If $f(x)$ is (C^m, A, B), then there is an open set $B' \supset B$ such that $f(x)$ is (C^{m-1}, A, B'). Functions of functions of class C^m are of class $C^m \cdots$. Finally, the above properties are local: If each p in B is in a neighborhood U such that $f(x)$ is $(C^m, A \cdot U, B \cdot U)$, then $f(x)$ is (C^m, A, B). (Received November 7, 1935.)

6. Professor Francis Regan: *On the admissibility of time series.*

In a paper by the author (Transactions of this Society, vol. 36 (1934), pp. 511–529) a time series is constructed in such a manner that the number $x(\alpha, \tau, t, \Lambda)$ is an element of the set $A[f(\alpha, \tau, t)]$, for every α, τ, t, and Λ, where $\tau = m \cdot 2^{-\sigma+1}$, $t = r \cdot 2^{-\sigma+1}$, $\Lambda = \rho \cdot 2^{-\sigma+1}$, and $r+m \leqq \rho$; and where α, ρ, m, r, and σ are positive integers. Here it is shown that for the same series the number $x(\alpha, \tau, t, \Lambda)$ is a member of the set $A[f(\alpha, \tau, t)]$, for every α, τ, t, and Λ, where $\Lambda = \rho \cdot 2^{-\sigma+1}$ and $t+\tau \leqq \Lambda$, with α, ρ, and σ as positive integers. (Received November 13, 1935.)

7. Mr. W. H. Ingram: *On the dynamics of commutator machines.*

The discovery of the analogy between relative angular velocity of commutator and brush in the theory of a commutated electrical nexus and the angular velocity of a system of moving coordinates in dynamics (Abstract 40-1-23, Philosophical Magazine, April, 1934, p. 844) suggests the possibility of establishing, for the electrical circuits in a machine, an analogy to the inertial ellipsoid of Cauchy and Poinsot in particle dynamics. It is found that the ellipsoid is stationary with respect to the field and that two principal diameters coincide with the polar and inter-polar axes, respectively. Suitable quasi-coordinates for commutator machines of any complexity are obtained from the true coordinates by a rotation of the coordinate system about an $(n-2)$-space perpendicular to the plane of the polar and inter-polar axes. (Received November 8, 1935.)

8. Mr. E. H. Larguier: *On a method for evaluating the moments of a Bernoulli distribution.*

This paper gives the moments of a Bernoulli distribution, $(p+q)^n$, in the form of a polynomial in p (the probability that the event will occur in a single trial) in which the coefficients are functions of n and are determined by a recursion formula. (Received November 15, 1935.)

9. Dr. E. P. Northrop: *Note on a singular integral.* II.

This paper is a generalization of the results obtained by the author in an earlier note (this Bulletin, vol. 40 (1934), pp. 494–496), in which were obtained necessary and sufficient conditions for the convergence in the mean to $f(x)$, as $m \to \infty$, of the integral $(2\pi)^{-1/2}\int_{-\infty}^{+\infty} f(u)K(x-u; m)du$, where $f(x)$ is an arbitrary function of L_2, and $K(x; m) \epsilon L_2$ for every m. The main results of the present note are concerned with sufficient conditions in the case $f(x) \epsilon L_q$, $2 < q < \infty$; and with necessary conditions in the case $f(x) \epsilon L_p$, $1 < p < 2$, and $K(x; m)$ is for every m the Fourier transform in L_q $(1/p+1/q=1)$ of some function in L_p. The simplifications brought about in the conditions on the kernel when it is of the special form $K(x; m) = mk(mx)$ are also discussed. (Received November 15, 1935.)

10. Professor A. H. Copeland (Guggenheim Fellow): *A critique of the continuum.*

It is the contention of this paper that the conventional postulational sys-

tems for the continuum are inconsistent. The inconsistency can be avoided by the introduction of a canon for postulation which prescribes certain alterations of these systems. When such changes have been effected, it becomes obvious why the original schemes are self-contradictory. Most of the classical results can be obtained from the altered set of postulates. There are, however, the following notable exceptions: the Richard paradox is resolved, a proof is given that the continuum cannot be well-ordered, and Zermelo's axiom is shown to be untenable. (Received November 15, 1935.)

11. Mr. W. E. Sewell: *Location of the level curves of Green's function.*

Let $w=f(z)$ map the exterior of the unit circle in the z plane conformally on the exterior of a simply connected region R in the w plane, carrying the point $z=\infty$ into the point $w=\infty$. This mapping carries the circle $|z|=\rho>1$ into an analytic Jordan curve C_ρ, and as ρ approaches 1 the curve C_ρ approaches C, the boundary of R. The minimum distances of a point on C from the closed set C_ρ and of a point on C_ρ from the closed set C depend upon ρ and C. In this paper it is shown that each of these distances is bounded by $M(\rho-1)^\mu$, where M and μ are constants depending only on C. A typical result is the following: Let $w=f(z)$ map the exterior of the unit circle on the exterior of a Jordan curve C in the w plane, carrying the point $z=\infty$ into the point $w=\infty$. Then for $1<\rho<2$ no point of C lies closer to C_ρ than $M(\rho-1)^2$, M depending only on C. (Received November 15, 1935.)

12. Mr. Marshall Hall: *A note on null sequences.*

A linear recurring sequence is a null sequence modulo m if every term after a certain point is divisible by m. A sequence is said to be p-adically null if it is a null sequence modulo every power of p. It is shown that a necessary and sufficient condition for a sequence to be p-adically null is that p divide every coefficient of the recurrence. It is, however, possible to construct a sequence satisfying a given recurrence, whose last coefficient is divisible by p, which shall be null modulo p^i in a non-trivial manner. (Received November 18, 1935.)

13. Dr. Nilan Norris: *Convexity properties of generalized mean value functions.*

Some investigations concerning the behavior of the second derivatives of four of the more important types of generalized mean value functions indicate that, although deductions as to convexity properties of the various means as functions of t must be very carefully guarded, certain inferences may be drawn. These conclusions are useful in applications of properties of the chief types of mean value functions to statistical theory, especially to index number theory. (Received November 18, 1935.)

14. Professor I. A. Barnett and Dr. C. W. Mendel: *On a certain integral equation quadratic in the unknown function.*

The problem considered in this paper is to find all real valued continuous functions $y(x)$ defined on $0\leqq x\leqq 1$, and satisfying the integral equation

$y^2=(y-\kappa)\int_0^1 y dx$, where $\kappa(x)$ is a prescribed continuous function on this interval. It is shown that the solution of the given equation may be made to depend upon a step function $\epsilon(x)$ taking on only the values $+1$ and -1 on $(0, 1)$. A step function is said to be of type r if it has precisely $r-1$ discontinuities none of which is isolated. A solution is said to be of type r if the associated step function is of type r. The principal result of this paper is as follows: Let M and m denote, respectively, the absolute maximum and minimum of $\kappa(x)$ on $(0, 1)$. Let $\lambda(c)=\int_0^1[(1-\sqrt{1-c\kappa})/c]dx$. Then, necessary and sufficient conditions that there shall exist a unique, real valued, continuous solution $y(x)$ of type 1, are that (1) $\kappa(x)$ changes sign on $(0, 1)$, (2) $\int_0^1 \kappa(x)dx \neq 0$, and (3) $\lambda(1/M)\geqq 0 \geqq \lambda(1/m)$. As an illustration, it turns out that for the function $\kappa(x)\equiv a(x-\alpha)$, $(0<\alpha<1)$, the integral equation will have a solution of the type described if, and only if, α lies on the middle ninth of the interval $(0, 1)$ excluding $\alpha=1/2$. (Received November 19, 1935.)

15. Mr. Garrett Birkhoff: *A note on topological groups.*

It is proved that a topological group (or "Hausdorff" group) satisfying Hausdorff's first countability axiom, is metrisable. This was previously known only under assumption of Hausdorff's second countability axiom. (Received November 20, 1935.)

16. Professor R. V. Churchill: *Temperature distribution in a slab of two layers.*

The Laplace transformation is used to find the variable temperature distribution formula for a slab of finite thickness consisting of two layers of different materials, when the initial temperature distribution is arbitrary. The purpose of the paper is not only to derive a new temperature formula, but also to illustrate a procedure by which the Laplace transformation and its inverse can be used in such problems in a dependable manner. The Mittag-Leffler partial fractions expansion and contour integrals are used in establishing the inverse transformation. (Received November 20, 1935.)

17. Professor J. D. Mancill: *The minimum of a definite integral with respect to unilateral variations.*

This paper is devoted to a rather exhaustive treatment, by comparatively general methods, of both necessary conditions and sufficient conditions for a strong relative minimum with respect to unilateral variations in plane problems in the calculus of variations, *without the hypothesis of regularity.* The analogous problem in space of three dimensions is also treated but the results are not as exhaustive. Both necessary conditions and sufficient conditions are obtained for the space problem but only under rather restrictive hypotheses. This fact and the fact that many of the difficulties encountered in the two problems differ widely, make it desirable to treat them separately. (Received November 20, 1935.)

18. Professor Dunham Jackson: *Orthogonal polynomials in two variables: formal properties.*

This paper is concerned with the construction and formal properties of

systems of orthogonal polynomials in two variables, which present some non-trivial points of novelty in comparison with the corresponding theory in one variable, particularly in connection with the orthogonal transformation of the set of polynomials of specified degree induced by a linear transformation of the variables under which the region of definition and the weight function are invariant. (Received November 21, 1935.)

19. Dr. W. C. Randels: *On the summability of Fourier series.*

Necessary and sufficient conditions for L, L', $\bar{L}$, and $\bar{L}'$-effectiveness of regular methods of summation of a general type are given. This type includes all triangular methods. (Received November 21, 1935.)

20. Mr. Alvin Sugar: *On universal Waring theorems for cubic functions.* Preliminary report.

This is the second of a series of papers in which the author hopes to verify some special cases of the following conjecture. Consider the polynomial $F_n(x) = M_{n-1}[x, n] + \cdots + M_1[x, 2] + x$, where $M_{n-1}, \cdots, M_1$ are non-negative integers and $[x, k] = (x+k-2) \cdots x(x-1)/k!$ (we may, by analogy, speak of the value of $F_n(x)$ for $x \geqq 0$ as nth degree polygonal numbers). In this paper the writer makes the conjecture that every positive integer is a sum of $s = \sum_{i=1}^{n-1} M_i + n$ values of $F_n(x)$ for $x \geqq 0$. It is to be noted that for $M_{n-1} \geqq \sum_{i=1}^{n-2} [n-(i+2)]M_i + 2n - 3$ such theorems would be ideal universal Waring theorems, i.e., there exists an integer $I(M_i, n)$ which is not a sum of fewer than s values. This paper establishes such theorems for the polynomials $(x^3-x)m/6 + (x^2-x)n/2 + x$, where m divides n. The methods are similar to those of a previous paper by the author entitled *A cubic analogue of the Cauchy-Fermat theorem.* (See abstract 41-11-410.) The constant employed here is that obtained by Webber. (Received November 21, 1935.)

21. Mr. H. S. Zuckerman: *New results for the number $g(n)$ in Waring's problem.*

This paper is a continuation of the work described in a preliminary report (abstract 41-3-163). Since then Vinogradow has published (Annals of Mathematics, vol. 36 (1935), pp. 395–405) another proof that $G(n) \leqq s = [n(6 \log n + \log 216 + 4)]$. The constants in this new proof are evaluated to obtain a value N such that all integers greater than N can be expressed as the sum of s positive or zero integral nth powers. A method for treating the integers greater than zero and less than $N+1$ without the use of tables is developed. As an illustration, ideal universal Waring theorems are proved for $h = 15, 16, 17, 18, 19, 20$; that is, the formula $g(n) = 2^n + [(3/2)^n - 2]$ is verified for these values of n. (Received November 21, 1935.)

22. Dr. R. D. James: *The number of representations of an integer as a sum of twelve, sixteen, or twenty squares.*

Let $N(2^\alpha m, 4s+4)$ denote the number of representations of an integer $2^\alpha m$, $\alpha \geqq 0$, m an odd integer >0, as a sum of $4s+4$ squares. Let $\sigma_{2s+1}(m) = \sum d^{2s+1}$, where the sum is over all divisors d of m. The problem of the pres-

ent paper was suggested by the fact that $N(2^\alpha m,\ 12)=c_0(\alpha)\sigma_5(m)$, if $\alpha\geqq 1$, *but not if* $\alpha=0$. It was thought that a similar result might hold for $N(2^\alpha m,\ 4s+4)$ for $s\geqq 3$. The main result of the paper is that this is not so when $s=3$ or 4. It is proved that for $s=3$ or 4 and any $\alpha\geqq 0$ no relations of the form $N(2^\alpha m,\ 4s+4)=c_{2s+1}(\alpha)\sigma_{2s+1}(m)$ can hold for all integers m with $c_{2s+1}(\alpha)$ independent of m. (Received November 21, 1935.)

23. Professor Nathan Altshiller-Court: *On the Cevian tetrahedron.*

If the lines joining the point M to the vertices of the tetrahedron $(T)\equiv ABCD$ meet the respectively opposite faces of (T) in the points A', B', C', D', the tetrahedron $(T')\equiv A'B'C'D'$, the "Cevian tetrahedron of M for (T)," is obviously homological to (T). It is shown that (i) the plane of this homology is the tetrahedral polar plane of the point M with respect to both (T) and (T'); (ii) the anharmonic ratio of this homology is equal to -3, irrespective of the choice of M. If we construct, in turn, the Cevian tetrahedron (T'') of M for $(T'),\cdots$, the anharmonic ratio of any four consecutive tetrahedrons is constant and equal to 4/7. (Received November 21, 1935.)

24. Professor V. W. Adkisson: *On the groups associated with certain cyclic curves.* Preliminary report.

This note deals with groups of transformations associated with each of the cyclicly connected continuous curves on a sphere having only a finite number of simple closed curves such that the complementary domain boundaries are homeomorphic. These transformations are analogous to the groups associated with the regular polyhedra. Each curve is unique, and has a unique group except one. This curve, in which each region boundary has three branch points of order four and one of order three, may have one of two groups of transformations; the octahedral group, or the dihedral group of order eight. If reversal of sense on the region boundaries be permitted, the octahedral group is extended to a group of order 48, generated by P and Q, $P^2=Q^3$, $(PQ)^4=1$. The dihedral group is extended to a group of order 16 generated by S and T, $S^8=T^2=1$, $T^{-1}ST=S^{-1}$. (Received November 23, 1935.)

25. Professor H. J. Ettlinger: *Cauchy fields of ordinary differential equations.*

Let R be the set of points, (x, y), where x is on (0, 1) and all real values of $y\equiv(y_1,\cdots,y_m)$, and let $f(x, y)$ be a real function defined in R. If $f(x, k)$, where k is a constant, is integrable (Lebesgue) and (t_{in}) defines a fine net on $(x_0, 1)$, we will call the uncountable collection of functions $y_n(x)=y_{i-1,n}+\int_{t_{i-1,n}}^{x} f(t,y_{i-1,n})dt$ on $(t_{i-1,n}, t_{in})$, $y_{0n}\equiv y_0$, $x_{0n}\equiv x_0$, the Cauchy field of $y'=f(x, y)$ through the point (x_0, y_0) of R. It is proved that (i) there exists a subsequence of the Cauchy field which converges to an absolutely continuous limit function, (ii) if this subsequence is equi-absolutely continuous and $f(x, y)$ is continuous in y, the limit function satisfies the equation (1): $y(x)=y_0+\int_{x_0}^{x} f(t,y)dt$, (iii) the Osgood property is established, namely, the upper and lower bound functions of the

field are solutions of (1) and through every point between them there is at least one solution of (1). Related properties are established for the non-unique solutions of (1). (Received November 23, 1935.)

26. Mr. O. H. Hamilton: *Non-unique solutions of first order ordinary differential equations.*

By making use of results announced by Professor H. J. Ettlinger, theorems concerning the properties with respect to continuity of the non-unique solutions of first order ordinary differential equations are demonstrated under hypotheses assumed by Professor Ettlinger. It is shown that under these hypotheses a differential equation, $y'=f(x, y)$, having a non-unique solution at a point P can be arbitrarily approximated by a differential equation having a unique solution at that point. It is further shown that $y'=f(x, y)$ may be arbitrarily approximated by a differential equation having a unique solution over a countable dense set of points in the region. The diameter of a non-unique solution is defined, and it is shown that the set of points in the region which lie on non-unique solutions of diameter greater than a given constant, K, is a closed set of points and that the set of all points which lie on non-unique solutions is the sum of a countable number of closed point sets. (Received November 23, 1935.)

27. Professor C. O. Oakley: *On semi-linear equations.*

In this paper the author continues his study of semi-linear equations, i.e., equations of the form $u_0+\sum m_i|u_i|=0$, where the u's are linear forms in two variables and the m's are constants. Special stress is put upon equations whose solutions are real in character. The general treatment considers the determination of the semi-linear equation which represents each of p regions of the plane formed by n lines. (Received November 23, 1935.)

28. Professor R. G. Archibald: *Highly composite ideals.*

In an earlier paper the author obtained results on the highly composite numbers defined in 1915 by S. Ramanujan. The present paper defines an ideal different from the unit ideal as highly composite if the number of its divisors is greater than that of every ideal of smaller norm and not less than that of every ideal of the same norm. Analogues of the properties of highly composite numbers are sought for these highly composite ideals. Among the results obtained are the following: For an arbitrary algebraic number field, it is shown that the reciprocals of the norms of the highly composite ideals form a convergent series. Where n is the degree of the field and x is an arbitrary positive integer, there always exists a highly composite ideal of norm greater than x and not greater than $2^n x$. (Received November 23, 1935.)

29. Dr. J. H. Curtiss: *A note on the degree of polynomial approximation.*

By a demonstration involving theorems of Fejér and Jackson, it is established that if a function $f(z)$ is analytic interior to an analytic Jordan curve C, is continuous in the corresponding closed region, and has an rth derivative satisfying a Lipschitz condition of order $\alpha \leqq 1$ on C, then there exist polynomials

$p_n(z)$, depending on r and α, such that $f(z)-p_n(z)=O(n^{\alpha+r})$, for $r=0, 1, \cdots$. An application is given to the study of Lagrange interpolation in regularly distributed points, and to the problem of determining the degree of approximation of certain Riemann sums closely identified with the Lagrange polynomials. (Received November 25, 1935.)

30. Dr. J. H. Curtiss: *The Jacobi series on an unrestricted lemniscate.*

This paper is a continuation of the study undertaken by the author of the properties of the Jacobi series on the boundaries of its regions of convergence (see abstract 41-1-28). By the use of certain auxiliary functions constructed on the functions $\phi_k(z)$ introduced in the earlier paper and by means of the Jacobi series corresponding to the auxiliary functions, the author again obtains the analogues for the Jacobi series of some familiar theorems concerning the Taylor series on the circle of convergence; but now with special reference to the case in which the lemniscate of convergence has multiple points. A number of interesting irregularities appear in the theory in this case; for instance, abelian theorems break down at multiple points and class H_2 no longer contains class H_∞. The existence of these irregularities is established by examples. (Received November 25, 1935.)

31. Dr. T. L. Downs, Jr.: *Asymptotic lines through a planar point of a surface and lines of curvature through an umbilic.*

At a planar point (one at which all three coefficients of the second fundamental form of the surface vanish) the classical theorems concerning the asymptotic directions and the asymptotic lines fail to hold. Nevertheless, there exists a finite set of possible tangent directions for the asymptotic lines through the point. The present paper shows that there is tangent to a given direction of this set a unique asymptotic line in the most general case, and two distinct asymptotic lines in the next most general case. While there exists a similar set of possible tangent directions for the lines of curvature through an umbilic, it turns out that a given direction of this set has in general either a single line of curvature or an infinite number of lines of curvature tangent to it, depending upon certain definite conditions. (Received November 25, 1935.)

32. Professor Cornelius Lanczos: *A new approximation method in solving linear differential equations with rational coefficients.*

In the method outlined previously (see abstract 41-3-108) further improvements are obtained. Legendre's polynomials are replaced by Tshebisheff's polynomials which permit a more even distribution of the error. The simple algorithms for these polynomial make it possible to estimate the asymptotic behaviour of the coefficients and prove the convergence. Applications to the approximation of the error integral, the integral logarithm, the Gamma function, Bessel's functions, show the rapid convergence of the method. (Received November 25, 1935.)

33. Professor Deane Montgomery and Dr. Leo Zippin: *Many parameter groups in n-space.*

If x is a point in n-space and t a k-dimensional vector, let $T(x; t)$ denote a function with values in the n-space, continuous in x and t simultaneously. Further, suppose that $T[T(x; t_1); t_2] = T(x; t_1+t_2)$. Among other results, we prove that if $k \geqq n-2$ then in order that $T(x; t)$ be topologically equivalent to the k-parameter translation group in n-space, it is necessary and sufficient that for each point x_0 there exist a sphere S containing it and a positive N such that for *all* $|t| > N$ and *all* points x in S, $T(x; t)$ *is not in* S. The theorem is comprehensive for 3-space. For greater values of n and general k, our problem can be shown to be equivalent to an interesting unsolved problem in topological products. (Received November 25, 1935.)

34. Professor C. N. Moore: *On restricted convergence and restricted summability of double series.*

If the partial sums, s_{mn}, of a double series, $\sum u_{mn}$, converge to a limit when m and n become infinite while obeying the restriction $0 < k < m/n < K$, where k and K are constants, the series is said to be restrictedly convergent. Restricted summability for any method of summation which replaces the s_{mn} by a related sequence, σ_{mn}, is defined in an analogous manner. The notion of restricted convergence and restricted summability was first introduced by the author in connection with the study of the summability of the double Fourier series, where it was shown to have special significance (Mathematische Annalen, vol. 74 (1913), pp. 555–572). Later Bochner showed that the notion had similar significance in connection with the Poisson summation formula (Mathematische Annalen, vol. 106 (1932), pp. 56–63). More recently Lösch has shown that a restrictedly convergent double series is not necessarily restrictedly summable by any regular transformation whatsoever, but that it is restrictedly summable by transformations of the Cesàro or Euler-Knopp type (Mathematische Annalen, vol. 110 (1934), pp. 33–53). It is the purpose of the present paper to show that a similar result holds for certain means of Nörlund type. (Received November 25, 1935.)

35. Miss Alta Odoms: *On the logarithmic mean of double Fourier series.*

The purpose of this paper is to establish sufficient conditions for the summability of the Fourier development of an integrable (L) function by Riesz's logarithmic means at a given point (x_0, y_0) to a sum S. Let a_{pq} be the Fourier coefficients of $f(x, y)$, $s_{ij} = \sum_{p=1}^{i} \sum_{q=1}^{j} a_{pq}$, and $S_{mn} = \sum_{i=1}^{m} \sum_{j=1}^{n} s_{ij}/ij$. It is shown that when $f(x, y)$ satisfies certain conditions, then $\lim_{m,n\to\infty}(S_{mn}/\log m \log n)$ exists and is equal to S. The results obtained are generalizations of results contained in a paper by G. H. Hardy (Quarterly Journal of Mathematics, Oxford Series, vol. 2 (1931), pp. 107–112) on the logarithmic mean of a single Fourier series. (Received November 25, 1935.)

36. Professor W. C. Risselman: *On a problem of approximation associated with a periodic Stieltjes fraction.*

The least square problem associated with the continued fraction

$-p_n/(q_n-z)]_1^\infty$, where p_n and q_n are real numbers satisfying $p_n>0$, $p_{n+k}=p_n$, and $q_{n+k}=q_n$ $(n=1, 2, \cdots)$, is studied. For non-real z, the fraction converges and equals $\int_{-\infty}^{\infty}(x-z)^{-1}d\psi(x)$. The monotonic function $\psi(x)$ is examined and a convergence theorem is established. Let $Q_n(x)$ be the denominator of the nth convergent. The convergence proof is made to depend on the fact that $Q_n(x)/(p_1p_2\cdots p_{n+1})^{1/2}$ remains bounded as $n\to\infty$ on the interval or intervals on which the approximation is made. (Received November 25, 1935.)

37. Professor I. J. Schoenberg: *On the zeros of successive derivatives of integral functions.*

J. M. Whittaker (Proceedings of the London Mathematical Society, (2), vol. 36 (1934), pp. 451–469) proved recently the following theorem: Let $f(x)$ be an integral function for which (1) $\overline{\lim}_{r\to\infty}\log M(r)/r<1/2$, and (2) $f^{(n)}(-1)f^{(n)}(1)=0$, $(n=0, 1, 2, \cdots)$. Then $f(x)=0$ identically. Whittaker remarks, by consideration of the function $\sin(x+1)\pi/4$, for which $\overline{\lim}\log M(r)/r=\pi/4>1/2$, that the number $1/2$, on the right side of (1), cannot be replaced by any number $>\pi/4$. He conjectures that $\pi/4$ is the best constant in the condition (1). A verification of this conjecture is contained in the following theorem: Let $f(x)$ be an integral function for which (3) $\overline{\lim}_{r\to\infty}\log M(r)/r<\pi/4$, and such that every one of its derivatives $f(x), f'(x), f''(x), \cdots$ vanishes somewhere between -1 and $+1$; then $f(x)=0$ identically. (Received November 25, 1935.)

38. Dr. Leo Zippin: *Dual abelian groups.*

This paper forms a natural complement and generalization of a paper by Professor J. W. Alexander and the author on *Discrete abelian groups and their character groups* in the Annals of Mathematics, vol. 36 (1935). The guiding new theorem is: If A and B are "sufficiently numerous" groups of characters of each other, they determine topologies on each other in which each becomes the group of all continuous characters of the other. (Received November 25, 1935.)

39. Professor J. H. Roberts: *Collections filling a plane.*

The present paper contains the following two results: (1) There exists an upper semi-continuous collection G filling a plane S such that every element g of G is a bounded continuous curve. In fact the element g is either an arc or is the sum of three arcs joined so as to form the letter H. (2) There does not exist an upper semi-continuous collection G of arcs filling a plane S. This second result contradicts the statement which the author presented in April, 1935. (See abstract 41-5-196.) (Received November 25, 1935.)

40. Dr. E. W. Titt: *Cauchy's problem for the non-linear hyperbolic differential equation in three independent variables.*

This paper presents a theory which seems to offer a generalization of the method and the results of H. Lewy in the case of two independent variables (Mathematische Annalen, vol. 98, (1928), p. 179). We use a two-dimensional

characteristic theory (see abstract 41-3-103). In order to carry through the existence theorems we find it sufficient that our initial strip be analytic in one direction but merely having a certain order of regularity in the other direction. These directions are characterized geometrically in terms of the geometry of the characteristic cone. In the course of our work we are led to the consideration of existence theorems for partially analytic solutions of a system of first order partial differential equations. (Received November 25, 1935.)

41. Professor W. M. Whyburn: *Critical sets for functions.*

Difference quotients are used to define critical points for general single-valued functions of n real variables. Critical sets of several types are defined and studied. In the case where the functions are continuous, it is shown that the existence of two critical sets of minimal type implies the existence of a set of minimax type. (Received November 25, 1935.)

42. Professor R. L. Wilder: *Sets which satisfy certain avoidability conditions.*

Relations between certain definitions of i-avoidability at a point (i a dimension number) and of non-i-cut-points are established for various kinds of spaces. As examples of these definitions, a metric space M is *completely i-avoidable* at P if for $\epsilon>0$ there exist δ and η such that $\epsilon>\delta>\eta>0$ and every γ^i of $F(P, \delta)$ is $\backsim 0$ on $S(P, \epsilon)-S(P, \eta)$; *locally i-avoidable* at P if every γ^i of $F(P, \delta)$ is $\backsim 0$ on $M-S(P, \eta)$; P is a *non-i-cut-point* if every γ^i of $M-P$ is $\backsim 0$ on $M-P$. Among the theorems obtained in applying the notions are these (hereafter $i=0, 1, \cdots, n-2$, and sets are in E_n): In order that a simply i-connected compact J^{n-1} (=connected, locally i-connected) should have only simply i-connected *g.c.* $(n-1)-m$.'s as boundaries of its complementary domains, it is necessary and sufficient that it have only non-i-cut-points. Among the sets J^{n-1}, those that have only *g.c.* $(n-1)-m$.'s as boundaries of their complementary domains are characterized by the fact that they are completely j-avoidable for $0\leqq j\leqq n-3$ and locally $(n-2)$-avoidable. The diameters of the complementary domains of a compact J^{n-1} form a null sequence, and the domains are almost all simply i-connected. (Received November 25, 1935.)

43. Dr. D. G. Bourgin: *The problem of the sheet.*

An approximation method has been developed for the problem of the clamped sheet with bending forces neglected. A novelty in the analysis is that the stresses are used rather than the strains. In a sense, an inverse problem has been solved since what is actually accomplished is the determination of the pressure (and attendant stresses) required to deform a square sheet into a given contour. The result involves the solution of an infinite set of linear equations in an infinite number of unknowns. The variation integral for demonstrating uniqueness turns out to be formally identical with the usual one in the strains except as regards sign of one term. The subsequent determination of the strains is given by an equation of hyperbolic type, and it is shown that the boundary conditions are consistent. (Received November 26, 1935.)

44. Dr. D. G. Bourgin: *Group velocity.*

The Rayleigh-Kelvin definition of group velocity may be generalized to phase arguments non-linear in x and t. The generalization is shown to be significant by exhibiting a class of dissipative media defined by a differential equation for which it is proved that the velocity of propagation of the avaiable energy is precisely the generalized group velocity. The demonstration depends on an easy modification of the equation of continuity. In this connection it is shown that the real meaning of the "stationary phase" principle is closely connected to that of the "steepest descent" method, the difference lying solely in the choice of contours. The first utilizes those for which $R.\ P.$ is constant, thus leading to Fourier integral rather than Laplace integral developments. (Received November 26, 1935.)

45. Dr. J. F. Randolph: *Carathéodory linear measure and Vitali's theorem.*

If A is an unrestricted plane set and F is a family of closed sets associated with A under certain conditions involving Lebesgue plane measure, the Vitali theorem states that there exists a sequence of mutually exclusive closed sets selected from F whose union contains all of A except a subset of Lebesgue plane measure zero. With A unrestricted, it has not been proved that under analogous conditions on F involving Carathéodory linear measure, there exists a sequence of mutually exclusive closed sets in F whose union contains all of A except a set of Carathéodory linear measure zero. In this paper it is proved, however, that this conclusion follows for all sets A restricted by two conditions. That these conditions are natural ones is shown by the fact that their analogues for Lebesgue measure are satisfied by all sets A. (Received November 26, 1935.)

46. Professor Henry Blumberg: *On the symmetrical structure of general point sets.*

This paper relates to questions that immediately suggest themselves concerning the symmetrical structure of a general point set in n-space, but which have hitherto not been systematically considered; for example, if S is an unconditioned planar set, what is the nature of the set of points P of the plane such that there are two directions of approach to P, the one having eventually on it only points of S and the other, eventually only points of the complement of S? Such a set of points P is always "ridé," a W. H. Young generalization of "denumerable" to the plane. The paper deals with a variety of analogous questions, and makes application of the results to general functions. (Received November 26, 1935.)

47. Dr. L. M. Blumenthal: *The metric characterization of a certain class of spaces.*

A class of spaces is defined by certain simple postulates and their metric characterization is obtained. The class of spaces includes the euclidean and non-euclidean spaces, and thus is obtained a unified treatment of these spaces, as well as other spaces of constant curvature. (Received November 26, 1935.)

48. Professor Leonard Carlitz: *On some asymptotic formulas in the additive theory of numbers.*

In this paper asymptotic formulas are derived for such sums as $\sum\alpha_1(m_1)\cdots\alpha_r(m_r)$, the summation extending over all positive integers m_i and primes p_j such that $n=m_1+\cdots+m_r+p_1+\cdots+p_k$. The $\alpha_i(m)$ are arithmetic functions satisfying certain restrictions. (Received November 26, 1935.)

49. Professor L. R. Ford: *Complex rational fractions.*

Let the complex rational fraction $z=p/q$ be represented by a sphere of radius $1/2q\bar{q}$ lying in the half-space above the z-plane and tangent to the plane at p/q. The properties of these spheres are discussed. The following theorem is proved, the steps in the proof being suggested by the preceding picture: *If, after a certain point, the convergents p_n/q_n of the continued fraction whose partial quotients are $a_0, a_1, a_2, \cdots$ (a_n a complex integer) have the property $|q_{n+1}|>|q_n|$, then the fraction converges.* (Received November 26, 1935.)

50. Dr. W. T. Martin (National Research Fellow): *Special regions of regularity of functions of several complex variables.*

In the theory of functions of several complex variables various types of regions occur as convergence regions of series development of analytic functions, notable ones being *Reinhardt regions* of absolute convergence of power-series, *circular regions* of uniform convergence of diagonal series (the *invariant convergence regions*) and *Cartan* (p, q)*-regions* (p, q, positive integers) of uniform convergence of certain other series. In this paper we investigate the problem of analytically continuing a function $f(x, y)$ beyond its associated circular and Cartan regions. New regions B_{pq}, D_{pq}, and $S_{\sigma\mu}(\sigma, \mu$, positive numbers), of regularity of $f(x, y)$ are obtained (i) by a consideration of the absolute summability of Borel's integral means of certain series developments of $f(x, y)$; (ii) by the study of the behavior of a class of functional transforms of $f(x, y)$; and (iii) by a consideration of the behaviour of $f(x, y)$ along a family of curves through the origin. (Received November 26, 1935.)

51. Professor R. L. Moore: *Concerning essential continua of condensation.*

The continuum M is said to have property N if for every positive number e there exists a finite set H of non-degenerate subcontinua of M such that every subcontinuum of M of diameter more than e contains some continuum of H. The author has shown (see a forthcoming issue of the Rice Institute Pamphlet) that no compact continuum with property N has an essential continuum of condensation. It is now shown that if the compact and webless continuum M does not have property N there exists an upper semi-continuous collection of mutually exclusive continua filling up M and forming, with respect to its elements, a continuum with an essential continuum of condensation. In order that the compact and webless continuum M should have no essential continuum of condensation it is necessary and sufficient that every non-degenerate subcontinuum of M should contain uncountably many local separating points of M.

In order that such a continuum should have an essential continuum of condensation it is necessary and sufficient that there should exist a positive number d such that if G is an upper semi-continuous collection of mutually exclusive continua filling up M and forming, with respect to its elements, a continuum with no continuum of condensation, then some continuum of G is of diameter more than d. (Received November 26, 1935.)

52. Dr. Rufus Oldenburger: *Characteristic roots of direct products of n-way matrices.*

W. E. Roth has studied the characteristic roots of direct products of 2-way matrices. In the present paper characteristic roots of direct products P of two or more n-way matrices $A=(a_{ij\ldots k}), \cdots, D=(d_{pq\ldots s})$ are defined in terms of $P-\lambda I$, where I is a generalized Kronecker delta and λ is a complex variable. By means of theorems which express space determinants of P in terms of space determinants of $A, \cdots, D$ relations between the space ranks of $A, \cdots, D$ and the characteristic roots of P are obtained. In a paper to appear in a forthcoming issue of the Transactions the author has studied the non-singular linear transformations that leave I invariant. These transformations also leave the characteristic roots of P invariant. (Received November 26, 1935.)

53. Professor M. J. Weiss: *Fundamental systems of units in normal fields.*

Certain theorems on fundamental systems of units in cyclic fields given by C. G. Latimer (American Journal of Mathematics, vol. 56 (1934), pp. 69–74) are extended to fundamental systems of units in algebraic fields normal with respect to the rational field. This is done by considering the integral group ring, formed from the group of the field, as a ring of operators for the group of units in the field. (Received November 26, 1935.)

54. Professor R. L. Jeffery: *The equivalence of sequence integrals and non-absolutely convergent integrals.*

If the function $F(x)$ is continuous and is a non-absolutely convergent integral of the measurable function $f(x)$ on the interval (a, x), then there exists a sequence of summable functions $S_n(x)$ tending to $f(x)$ almost everywhere for which $TS(f, a, x)=\lim_{n\to\infty}\int_a^x S_n dx=F(x), 0\leqq x\leqq a$. The sequence S_n is such that $S_n=f$ on E_n, $S_n=0$ elsewhere, and mE_n tends to $b-a$. The present paper is concerned with the converse problem: If $f(x)$ is measurable, and if $TS(f, a, x)$ exists and is continuous, is $f(x)$ integrable in the generalized Denjoy sense? The answer is in the affirmative when for every perfect set P the points of non-summability of f over P are non-dense on P. (Received November 26, 1935.)

55. Dr. Max Zorn: *On elementary number theory.*

The existence of the primitive root mod p is known to be an instance of the algebraic theorem: The roots of unity in a field form a cyclic group, if their number is finite. In this paper it is shown that a simplification of the standard proof enables us also to derive abstractly a theorem of Ore, which contains a theorem of Schoenemann-Hensel about finite fields. The primitive root for odd

prime-powers is explained by means of the Fermat-Schur theorem. The Lemma of Gauss (and its extensions by Gauss himself, Artin-Schreier, and Carlitz) turns out to be a special case of a well-known theorem in group theory; this analysis gives immediately generalizations to higher fields. (Received November 26, 1935.)

56. Professor W. D. Baten: *The frequency distribution for the mean of n independent chance variables when each is subject to the law* $y_0x^{p-1}(1-x)^{q-1}$.

This paper shows, by using certain results obtained from sampling theory and criterions for Pearson-type curves, which type represents the distribution of the mean of n independent chance variables when each is subject to the law $y_0x^{p-1}(1-x)^{q-1}$. (Received November 26, 1935.)

57. Dr. R. H. Cameron: *Almost periodic properties of bounded solutions of linear differential equations with almost periodic coefficients.*

This paper deals with the differential equation $D(X)=AX$, where A is a given *a.p.* matrix function and $D(X)$ denotes the matrix obtained by differentiating each element of X. It is assumed that the real part of the sum of the diagonal elements of A has a bounded integral and that the equation has a bounded non-singular solution. Under these conditions it is shown that the equation has a non-singular solution in which the norm of each row is *a.p.* It is also shown that if the group of transformations of the solutions by limiting translations which leave A invariant is abelian, then the equation has a non-singular solution each element of which has an *a.p.* absolute value and an argument whose derivative is equal to the quotient of two *a.p.* functions except at points where the argument is indeterminate. (Received November 26, 1935.)

58. Dr. Robin Robinson: *On the differential line-geometry of space associated with the linear conformal transformations of the dual sphere.* Preliminary report.

A one-to-one correspondence between the lines of space and the points of the dual sphere is established by means of Study's "Uebertragungsprinzip." The dual sphere is then subjected to conformal transformations and the resulting invariants of space line-geometry are studied, with special reference to ruled surfaces and rectilinear congruences. This topic has already been treated by Knothe (Mathematische Zeitschrift, vol. 38 (1933–34), pp. 45–69), but the present writer uses a somewhat different method of attack, which follows closely the invariant methods recently used in this country by Graustein. It is also expected that the present paper, when ready for publication, will contain a number of new results. (Received November 26, 1935.)

59. Dr. S. B. Myers (National Research Fellow): *Isometries of closed 2-dimensional analytic Riemannian manifolds into themselves.*

It is easily shown that if T is an isometry of a closed analytic 2-dimensional

Riemannian manifold into itself, either T is of finite period or else the manifold admits a continuous group of isometries into itself. If T has a fixed point, this holds without the hypothesis of analyticity. Thus the study of isometries is naturally divided into the periodic case and the case of continuous groups. The latter case is treated by methods initiated by W. Rinow (Mathematische Annalen, vol. 107 (1932), pp. 95–112). In the periodic case, relations between the topology of the surface, the fixed points and fixed curves of T, and the period of T are studied. An important tool in this latter study is the "minimum point" locus previously studied by the author (Proceedings of the National Academy of Sciences, vol. 21 (1935), pp. 225–227 and Duke Mathematical Journal, vol. 1 (1935), pp. 376–391). (Received November 27, 1935.)

60. Mr. R. B. Kershner: *On singular Fourier-Stieltjes transforms.*

According to the Riemann-Lebesgue lemma, a necessary condition for the absolute continuity of a distribution function $\sigma(x)$ is that $\lim_{t\to\pm\infty} L(t, \sigma)=0$, where $L(t, \sigma)=\int_{-\infty}^{\infty} e^{itx}d\sigma(x)$. The present paper considers a class of distribution functions, $\sigma=\sigma_a(x)$, $0<a<1/2$, for which $L(t, \sigma_a)=\prod_{n=1}^{\infty}\cos(a^n t)$. These functions are not absolutely continuous; in fact, they are constant up to a set of measure zero. It is shown that if a is rational then $\lim L(t, \sigma_a)=0$ does or does not hold according as $1/a$ is not or is an integer. (Received November 27, 1935.)

61. Professor E. K. Haviland: *On the momentum problem for distribution functions in more than one dimension.*

It is shown that for the existence of a distribution function whose spectrum is contained in a given set C of the plane and which possesses the preassigned momenta c_{nm}, $(n, m=0, 1, 2, \cdots; c_{00}=1)$, it is necessary and sufficient that the matrix $\|c_{nm}\|$ be non-negative with respect to C, in the sense that to any polynomial $\sum_{n=0}^{N}\sum_{m=0}^{M}a_{nm}x^n y^m$ non-negative for all (x, y) in C there corresponds the non-negative functional value $P_C=\sum_{n=0}^{N}\sum_{m=0}^{M}a_{nm}c_{nm}$. This implies the well-known criteria for the various standard momentum problems as special cases. It turns out that this unified and more general treatment of all these momentum problems is no more complicated than the several individual treatments to be found in the literature for these special cases. (Received November 27, 1935.)

62. Professor J. L. Synge: *The dynamical theory of electrical commutator machinery.* Preliminary report.

Ingram (Philosophical Magazine, vol. 17 (1934), p. 844) and Kron (Journal of Mathematics and Physics, vol. 13 (1934), p. 103) have applied general dynamical methods to commutator machinery. In both cases, however, it is assumed that the problem of machine performance is distinct from the problem of commutation, and in fact that it is possible to write down equations of performance without paying attention to the currents in the windings short-

circuited by the brushes. In the work now reported the problem is investigated starting from the Lagrange-Maxwell equations and using as a basis of approximation the assumption that the number of commutator-segments is infinite. The investigation does not confirm the validity of the assumptions of Kron and Ingram. For a machine with shunt and interpoles in which the width of the brush does not exceed that of one commutator segment, explicit conditions for sparkless commutation are obtained, and also equations of performance. These involve the ratio of the widths of brush and commutator segment. (Received November 29, 1935.)

63. Dr. Max Zorn: *On subanalytic spaces.* I.

A Hausdorff space is said to be subanalytic if it has a defining neighborhood-system of a certain property, meaning roughly that the neighborhoods near a point either are small or contain neighborhoods of this point, some exceptions of a definite character permitted. Several variations of this concept are studied; each type yields the existence of arbitrarily small decompositions into pieces with different discreteness properties. "Arbitrarily small" is defined with arbitrary coverings by open sets, not by finite ones as usual. There are relations to generalized metrisability (that is, existence of a complete monotonic development of arbitrary length), generalized separability (that is, existence of a dense set which is the sum of a chain of discrete point sets), and generalized perfect separability. (Received November 26, 1935.)

64. Count Alfred Korzybski: *Extensionalization in mathematics, mathematical physics, and general education: general semantics.*

This paper deals with the following topics: *Experimental* character of extensionalization. Results with "normal" persons, defectives, and "mentally" ill. Definitions of "intension" and "extension." "Similarity of structure" as condition of predictability. Review of extensionalization in mathematics. Review of extensionalization in physics. The Einstein theory extensionalized physics. Its influence on the quantum theory. Semantic definition of "number" and mathematics. The elimination of the mystery "why" mathematics. Elimination of difficulties in teaching mathematics. Extensional general linguistic devices applicable to daily life and elementary education. The *experimental* wide evidence of unexpected possibility of application of *physico-mathematical methods* to daily life, applicable to small children, defectives and "mentally" ill, as well as in general education. The solution of problems of mathematical "infinity." The solution of the mathematical theory of "types." Conclusion: Once physico-mathematical methods are properly *evaluated* and formulated, (General Semantics) *experimental* evidence shows that these methods and orientations have a most beneficial influence on general human adjustment, developing automatically human "mentality," character, stability. *Preventive character* of extensionalization. The importance, scientific and human, *of more and more general theories* (E. H. Moore). (Received November 22, 1935.)

65. Mr. W. H. Ingram: *The Heaviside problem for the non-uniform transmission line.*

By the Heaviside problem is meant the problem of finding the current at any point in the line at any time subsequent to the sudden imposition of a constant electro-motive force at one or more points anywhere in the line. A solution of Bromwich-Heaviside type is here obtained, after recourse to the theory of linear integral equations, in which Fredholm's determinant plays a part analogous to $H(p)$ in Carson's integral equation. The result is generalizable to any passive non-self-modulating electrical system, continuous or discrete, and to the case of vibrating strings and air-columns. (Received November 29, 1935.)

66. Professor H. W. Raudenbush, Jr.: *On the Hilbert-Netto theorem for algebraic differential equations.*

The analogue obtained by J. F. Ritt (*Differential equations from the algebraic standpoint*, Colloquium Publications of this Society, vol. 14) for algebraic differential equations to the Hilbert-Netto theorem associates, for a given system, to each form having all the solutions of that system a minimum power which is a linear combination of the forms of the system and their derivatives with forms for coefficients. The analogy to the theory of algebraic equations suggests that the exponents of these powers are bounded. In this paper an example is given of a system for which these exponents are not bounded. (Received December 2, 1935.)

67. Professor Harris Hancock: *Minkowski's geometry of numbers.*

This paper gives a discussion of the history of Minkowski's geometry of numbers with certain applications. (Received December 4, 1935.)

68. Mr. W. E. Sewell: *A generalization of Markoff's theorem.*

Let $P_n(z)$ be a polynomial of degree n in z and let $|P_n(z)| < M$ on a point set whose complement is simply connected. Then $|P_n'(z)| < Kn^2$ on the set, K being a constant independent of n and z. This theorem is proved by a result stated in the writer's recent abstract, *Location of the Level Curves of Green's Function*. The present result is extended with suitable restrictions on the set to generalized derivatives and applied to the theory of approximation by polynomials. (Received December 15, 1935.)

69. Professor Marston Morse and Dr. A. E. Pitcher: *Invariants of closed extremals.*

The Poincaré rotation number has the following generalization. Let g be a closed extremal of length ω. Let x denote length on g. Let g^σ denote the closed extremal obtained by tracing g an integral number σ of times. Let ν_σ denote the number of conjugate points of $x=0$ on g^σ. The limit as σ increases without limit of ν_σ/σ exists. It is termed the frequency number of g. Let T_σ denote the index of g^σ. The limit as σ increases without limit of T_σ/σ exists and

is equal to the frequency number. The extremal g determines a matrix A of constants. If no characteristic root of A has the absolute value 1, the frequency number of g is an integer. The index of g is equal to ν_1 plus the order of concavity of g minus the count of secondary extremals of period ω vanishing at $x=0$. The number of conjugate points of $x=0$ preceding $x=\sigma\omega$ is equal to ν_1 plus $\nu_{\sigma-1}$ plus the index of repletion of g^σ minus the count of secondary extremals vanishing at $x=0$, $(\sigma-1)\omega$, and $\sigma\omega$. The index T_σ can be determined by a finite constructive process when A and ν_1 are given. (Received December 16, 1935.)

70. Professor J. F. Ritt: *Indeterminate expressions involving an arbitrary function and its derivatives.*

Let u represent an arbitrary analytic function of x and A and B two polynomials in u and a certain number of its derivatives with analytic functions for coefficients. The problem considered here is that of attributing a meaning to the quotient A/B when u is such as to cause A and B to vanish identically in x. In the author's Colloquium Lectures a prescription was laid down for the interpretation of such indeterminate expressions, on the basis of which it was conjectured that, when $A=B=0$, A/B represents either a single analytic function or all analytic functions. The present paper verifies this conjecture for the case in which A and B involve no derivative higher than the first derivative. (Received December 11, 1935.)

71. Professor H. S. White: *Cross-points of lines on a cubic surface.*

A cubic surface contains 27 straight lines, each meeting 10 others. Of these 135 cross-points, there are certain sets of 6 (no two on any of the 27 lines) which are coplanar. These have been mentioned in a paper of I. Schur, but apparently not elsewhere. By the aid of elliptic parameters in a variable plane section of the surface, a direct method is shown for testing whether any plane contains more than three such points. As a new item it is proved that no plane except those through some one or more of the 27 lines contains more than 6 cross-points, and that all those having 6 points form a single set. (Received Dec. 19, 1935.)

72. Professor Morris Marden: *A Grace-Heawood theorem for the critical points of Green's function.*

Concerning the critical points of Green's function, Professor Walsh has recently published a number of theorems suggested by certain results regarding the zeros of the derivative of a polynomial. (See, for example, American Mathematical Monthly, vol. 42 (1935), pp. 1–17) The main theorem of the present paper, an analogue of the Grace-Heawood theorem, is the following: Let R be an infinite region with a finite boundary B of which B_1 and B_2 are any two closed branches. Let C_1 (center α_1, radius r_1) and C_2 (center α_2, radius r_2) be any two circles which enclose B_1 and B_2 respectively and which have no interior points in common. Then, if no critical point of $G(x, y)$, Green's function for R and pole at infinity, lies in the closed exterior of hyperbola

$H(C_1, C_2)$ (foci α_1 and α_2, transverse axis r_1+r_2), at least one critical point of $G(x, y)$ lies in each interior of $H(C_1, C_2)$. (Received December 29, 1935.)

73. Professor W. E. Roth: *On the matrices AB and BA.*

The present note is primarily concerned with the proof of the theorem: *If A and B are $n \times n$ matrices with elements in the commutative field F, then the necessary and sufficient condition that AB and BA are similar in F is that a non-singular matrix T with elements in F exists such that AT and $T^{-1}B$ are commutative.* In case one of the matrices, say B, is non-singular, the matrix $T^{-1}B$ satisfies the above theorem for then $AT=AB$ and $T^{-1}B=I$ are commutative. The fact here noted that AB and BA are always similar matrices if either A or B is non-singular is known. (Wedderburn, *Lectures on matrices*, Colloquium Publications, vol. 17 (1934), p. 25.) The above theorem, however, takes care also of the case where both A and B are singular. The sufficiency proof of the theorem is trivial. (Received December 29, 1935.)

74. Dr. S. C. Kleene: *A note on recursive functions.*

The general recursive functions of natural numbers (under the Herbrand-Gödel definition) are the functions obtainable by repeated applications of the operation of forming, from a given function $\rho(x_1, \cdots, x_n, y)$ such that $\rho(x_1, \cdots, x_n, y)=0$ has solutions for every $x_1, \cdots, x_n$, the function (denoted by $\epsilon y[\rho(x_1, \cdots, x_n, y)=0]$) which the least solution is of $x_1, \cdots, x_n$, and of substitution, from the three particular functions $x+y$, $x \cdot y$, δ^x. (Received December 31, 1935.)

75. Professor Salomon Bochner: *Summation of general Fourier expansions on closed Lie groups.*

Recently the author investigated the summability of multiple Fourier series by so-called spherical means. The resulting criteria may be easily extended from ordinary multiple Fourier series to Fourier expansions on closed semi-simple Lie-groups. In particular the summability by spherical Riesz-means of a sufficiently high exponent depends solely on the local behavior of the given function, the smallest admissible exponent depending only on the dimension of the underlying group and not its specific nature. A detailed account will appear in the Annals of Mathematics. (Received January 1, 1936.)

76. Professor W. C. Graustein: *A new form of the four-vertex theorem.*

The "Vierscheitelsatz," in its usual form, states that an oval has at least four vertices, that is, that the curvature of an oval has at least four relative extrema. The new form says that an oval has at least four *primary* vertices. By a primary vertex is meant an extremum of the curvature which, if a maximum, is greater than the average curvature, and, if a minimum, is less than the average curvature. (Received January 2, 1936.)

77. Professor W. C. Graustein: *Applicability with preservation of both curvatures.*

The determination of conditions necessary and sufficient that there exist a surface applicable to a given surface with preservation of both the total and mean curvatures constitutes a problem of classical differential geometry which has received no little attention. In this paper, various new conditions, all in invariantive form, are found, and the map of a surface satisfying these conditions on a surface applicable to it in the manner described is shown to have many interesting geometrical properties. (Received January 2, 1936.)

78. Professor G. T. Whyburn: *Irreducible and arc-preserving transformations.*

If A is a compact continuum, a continuous transformation $T(A)=B$ will be called irreducible provided no proper subcontinuum of A maps onto all of B under T; T is said to be arc-preserving provided the image of every simple arc is either an arc or a single point; if A is locally connected, T is said to be A-set reversing provided the inverse of every point in B is either a single point or an A-set in the sense of the cyclic element theory. These types of transformations are investigated and relations between them are cleared up. If A is locally connected and T is A-set reversing, then for each true cyclic element E_b in B there exists a unique cyclic element E_a of A such that $T(E_a)=E_b$ and T is a homeomorphism on E_a. Also, if A is locally connected and T is irreducible and arc-preserving, T is a homeomorphism on each true cyclic element of A; thus in particular if A is cyclicly connected, T is a homeomorphism. Consequently every continuous irreducible transformation of one simple closed curve into another is a homeomorphism. Other particular cases, notably that in which B is a dendrite, are studied. (Received December 20, 1935.)

79. Professor G. T. Whyburn: *Completely alternating transformations.*

A continuous transformation $T(A)=B$ which is not (1-1) will be called completely alternating provided that if x, $y\epsilon B$ and x_1, $x_2\epsilon T^{-1}(x)$, then $T^{-1}(y)$ separates x_1 and x_2 in A. In this paper it is shown that if A is a compact continuum and $T(A)=B$ is completely alternating, then B is a simple closed curve and A is atriodic. Thus if A is locally connected, A is either an arc or a simple closed curve. If A is a simple closed curve, T is equivalent to the transformation $w=z^k$ on the circle $|z|=1$, where k is a positive integer, in the sense that if this second transformation is denoted by $W(A')=B'$, then one can write $T(A)=H_2WH_1(A)=B$, where $H_1(A)=A'$ and $H_2(B')=B$ are homeomorphisms. If A is a simple arc, T is equivalent in the same sense to the transformation $x=\cos(k+\frac{1}{2})t$, $y=\sin(k+\frac{1}{2})t$ on the interval $0\leqq t\leqq 2\pi$, where k is a positive integer. Finally, if it is agreed to call a transformation T as above completely componentwise alternating provided $T^{-1}(y)$ separates any two components of $T^{-1}(x)$ in A, then any such T can be factored into the form T_2T_1 where T_1 is monotone and T_2 is completely alternating. (Received December 20, 1935.)

80. Mr. Garrett Birkhoff: *Partially ordered sets and the inclusion relation.*

This is an expository article describing recent advances and applications of the abstract theory of ordering. The only new results are: (1) the remark that every "simply ordered" system is a distributive lattice, (2) the precise statement of the correspondence (called to the author's attention by L. R. Wilcox) between lattices and the "extensionally attainable properties" of E. H. Moore, (3) the proof that every "dimension function" maps the lattice on which it is defined homeomorphically onto a modular lattice, and every "weight function" onto a distributive lattice, and (4) the observation that inclusion can serve as the only primitive idea of combinatorial analysis situs. (Received December 28, 1935.)

81. Mr. Garrett Birkhoff: *Moore-Smith convergence in general topology.*

It is shown that the "convergence of systems of sets" described in Abstract 41-9-355 is equivalent in any Hausdorff space H to an extension of Moore-Smith convergence. It is proved that use of this notion eliminates the undesirable distinction between neighborhood closure and sequential closure. Finally, "completeness" is defined from a philosophical and logical viewpoint by three simple properties. (Received December 28, 1935.)

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